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ABSTRACT

This guide was prepared to support a program of training for community specialists in contemporary and practical techniques of home energy conservation. It is designed to assist professionals in efficient operation of energy conservation programs and to provide ideas for expanding education operations. Eight major sections are presented: (1) Energy in Perspective; (2) Heat Transfer; (3) Weatherization; (4) Heating Systems; (5) Energy and Home Appliances; (6) Energy Efficient Design; (7) Energy in the Apartment; and (8) Energy in the Mobile Home. Each section contains subsections with discussions pertinent to the section topic. Graphs and figures supplement discussions. Primer study guides and a bibliography conclude the document. (Author/RE)

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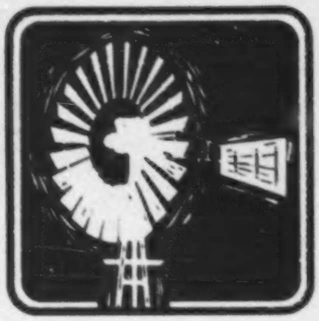

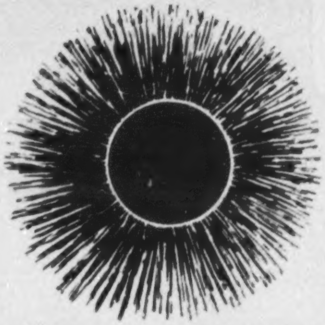

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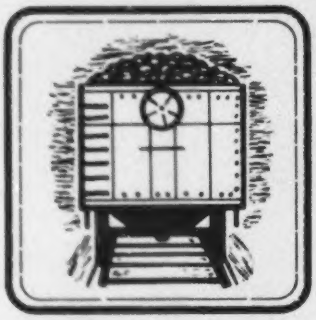

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Home Energy Conservation Primer

August 1979

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INTRODUCTION

The PRIMER is a revised document from the Home Energy Conservation Training Manual prepared for the Home Energy Conservation Training Program (HECTP) of the Technology Education Program of West Virginia University (1978-79). The basic principle of HECTP was to train community specialists in contemporary and practical techniques of home energy conservation and how to disseminate this information to West Virginia Citizens. The program extended it's training efforts to four West Virginia areas:

Morgantown, West Virginia	September 15, 1978
Parkersburg, West Virginia	September 22, 1978
Wheeling, West Virginia	October 6, 1978
Jackson's Mill State 4-H Camp (Weston, West Virginia)	October 20, 1978

The HECTP personnel were:

Dr. David L. McCrory	Project Director
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The HOME ENERGY CONSERVATION PRIMER is meant to assist professionals in the efficient operation of energy conservation programs and provide ideas for the expansion of their organization's operation. The editor hopes that the enclosed materials will assist you in serving your community in energy conservation education.

ACKNOWLEDGEMENTS

The editor would like to sincerely thank the efforts of several people who put many hours into editing, writing and revising the HOME ENERGY CONSERVATION PRIMER. They are:

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CREDIT

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Unit 5. Figure 5.15 (p. 16).
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PRIMER STUDY GUIDES

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unit 1

ENERGY IN PERSPECTIVE

by: S.G. Sauter

Over the past century, America's demand for energy has, on the average, doubled every 20 to 25 years. And, today, the U.S. is experiencing a shortage of traditionally plentiful energy supplies and, skyrocketing fuel prices.

More than one third of the world's energy is consumed by 6% of the world's population--those residing in the United States. At current rates of consumption, U.S. reserves of petroleum will last about 10 years, natural gas from 9-11 years and coal from 200-400 years. Furthermore, in 1978 the U.S. supplemented 24% of its total energy needs from foreign countries to maintain home demand levels. Because of our finite, traditional energy supplies, our ever-increasing demand for more, and costly dependence on supplementary foreign imports, a major problem facing U.S. citizens is how to slow rates of consumption and conserve our valuable energy supply. And, as a result of our demand for energy, other serious problems have arisen: America's land, water and air are becoming altered, polluted, and damaged from the search for, mining and use of non-renewable fossil fuels.

This unit will study how and why the U.S. has arrived at its present energy situation and make several recommendations for conserving our energy resources.

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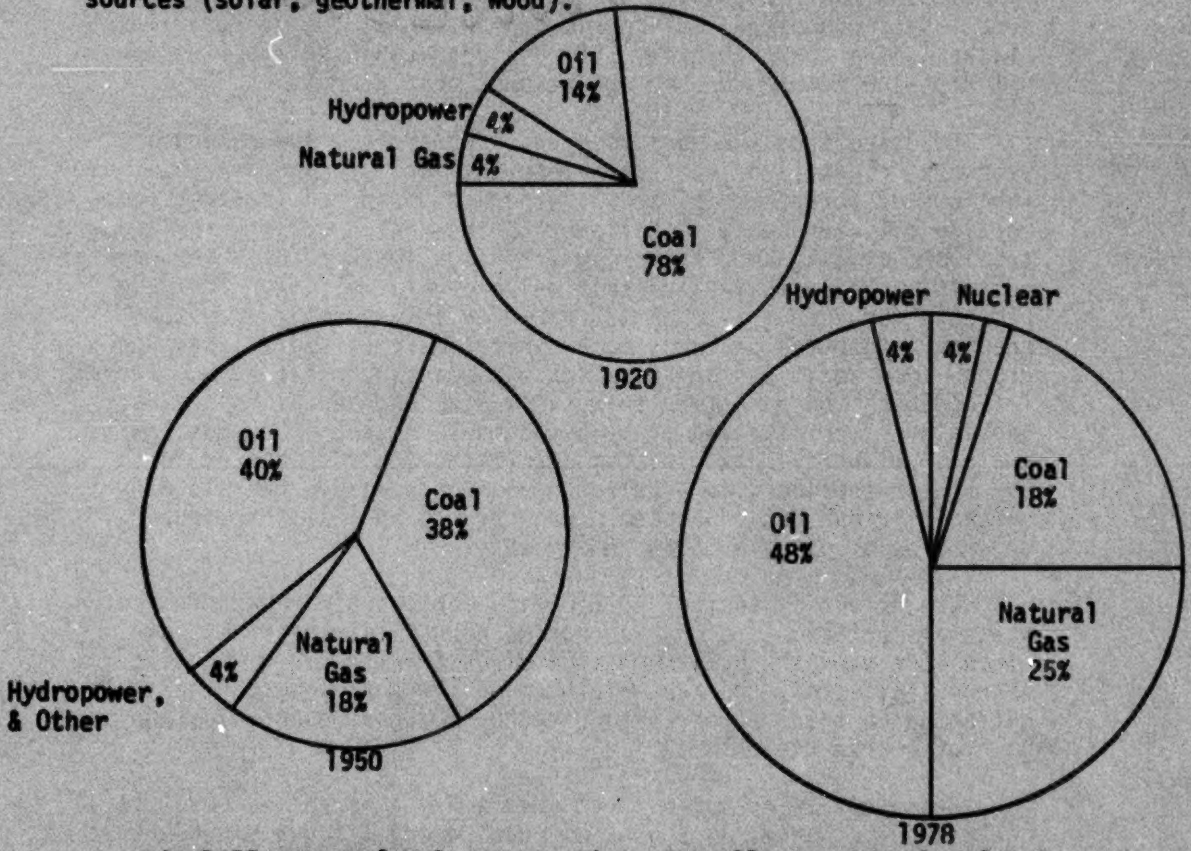
ENERGY IN PERSPECTIVE

Over the past century, the U.S. developed our current centralized energy system. This system requires readily available fossil fuels which when used up will not be replenished for billions of years. These fuels were formed from the decomposition of plant and animal matter under extreme pressure from geological change in the earth's crust. Use of fossil fuels which we have become so dependent on are dangerous to both human health and the earth's ecosystem. One hundred years ago, 75% of U.S. energy needs were met with wood. However, as seemingly endless supplies of oil, gas and coal were discovered as energy sources, the U.S. developed into an energy intensive, industrialized nation, finding use for these fossil fuels in a likewise endless variety of ways. In 1978, approximately 91% of our energy budget was derived from oil, natural gas and coal.[1] The remainder is made up of nuclear, hydroelectric and miscellaneous sources (solar, geothermal, wood).



At 1977 rates of U.S. consumption, 9 to 11 years supply of U.S. natural gas reserves are left and 10 years supply of U.S. petroleum reserves remain.[2] Coal is our largest fossil fuel reserve and is estimated to contain 200 to 400 years supply at current levels of use. These reserve estimates can be misleading, however, since they are based only on current levels of use and supply, they can change drastically as demand and supply patterns shift. For example, if coal were used to replace our current demand for oil and gas, a plan which many foresee as "the answer" to our energy problem, our coal supply would last approximately 60 years.[3]

Petroleum

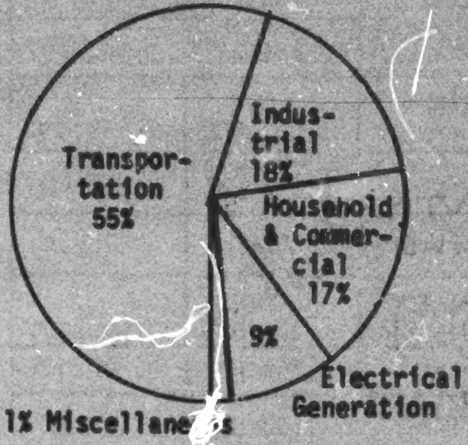
Defined as an oily, liquid solution of hydrocarbons, petroleum lies in certain rock strata below the earth's surface. Oil was first discovered in 1859 in Pennsylvania with commercial production following soon thereafter. As petroleum's versatility became apparent, more and more uses for it were developed, whereupon in 1978, U.S. dependence on oil for energy and petroleum products reached 48% of total U.S. energy resource consumption.

In the past 30 years, most U.S. petroleum has been produced from Texas, Louisiana, California and Oklahoma. However, 1977 saw Alaska as the fourth ranking U.S. oil producing state as the Alaska Oil Pipeline finally became operational that year.[2]

Produced from the various types of petroleum are numerous products, classified into two categories-fuel use and non-fuel use. Fuel use of petroleum is used to generate power and includes home heating oil, kerosene, distillate and residual fuel oils for industrial and utility use, natural gas liquids, bunker fuels for marine vessels, motor gasoline, diesel fuel and jet fuel. Non-fuel use products range from lubricants, paraffin and asphalt, to petrochemically derived products such synthetic fertilizers, pharmaceutical drugs, food additives and plastics encompassing nylon-spun materials for clothing and home furnishings, medical and dental apparatus, packaging materials, and everyday items such as hairbrushes, belts, small appliances, book binders, pens, flooring and counter tops. Everywhere one looks is a petroleum-based product. Petroleums' versatility can not be argued. However, as we shall see, our dependence on petroleum can be argued.

Broken out by sector, 1976 demand for petroleum was greatest in the transportation sector, accounting for 55% of that fuels use. Since 1947 when the U.S. Bureau of Mines first began collecting energy statistics, the sectorial demand for petroleum has generally conformed to the 1976 percentage although actual quantities consumed have of course risen.[4]

Petroleum is measured in barrels and one barrel is equal to 42 gallons. The barrel as a unit of measure and its quantity derives from the early history of the petroleum industry. The average heat content of crude petroleum is 5,800,000 BTU/barrel. Its various products contain anywhere from 5,248,000 BTU/barrel of motor gasoline to 6,287,000 BTU/barrel of residual fuel oil.[2]



U.S. Petroleum Use
1976 Percent Consumed by Sector

	1947	1976
	(Millions of barrels)	
Household & Commercial	385.3	1,104.2
Industrial	418.3	1,166.1
Transportation	1,050.3	3,480.4
Electrical Generation	75.5	559.0
Miscellaneous	60.4	40.0
Total	1,989.8	6,349.7

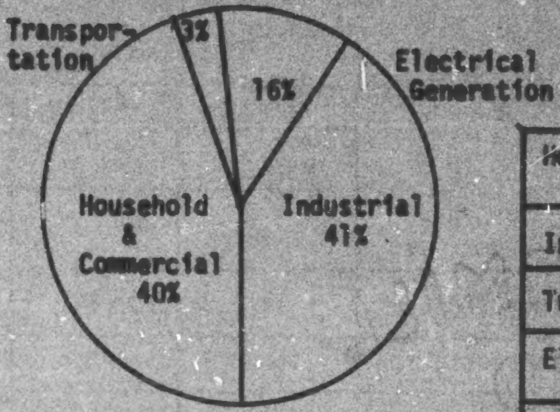
1947 & 1976: Millions of barrels of petroleum used by consuming sector in the U.S.

(Source: U.S. Bureau of Mines)

Natural Gas

Natural gas is primarily made up of methane, with some butane, propane and other gaseous hydrocarbons. Often found with petroleum, natural gas is produced in largest quantities from the same part of the country - Texas, Louisiana, Oklahoma, but also New Mexico and Kansas. In 1978, natural gas made up 25% of total U.S. energy consumed and has steadily decreased as part of our energy mix since the all time high was reached in 1971 at 32.9%. Almost wholly used as a fuel, natural gas is sometimes liquified as bottled gas but is generally used through means of tapping into pipelines. Space heating, cooling, and high-temperature industrial processes are the primary uses of natural gas.

In 1976, the industrial sector and household/commercial sector used an approximately equal share of natural gas, 41% and 40% respectively. However, this has not been the historical trend of natural gas consumption. The household and commercial sector slowly increased its share from 25% in 1947 to a steady 34% for the 10 year period between 1958 and 1967. Since 1968, natural gas consumption by this sector has fluctuated from 32% in 1970 to an all time high of 40% in 1976.[4] Industry has steadily decreased its use of natural gas as a result of various legislative mandates requiring a switchover to oil, and more recently to coal. Unlike petroleum, natural gas is measured in cubic feet becase of its gaseous state. The average BTU heat value of natural gas is 1,035,000 BTU/1,000 cubic ft.[2]



U.S. Natural Gas Use
1976 Percent Consumed by Sector

	1947	1976
	(Million Cubic Feet)	
Household & Commercial	1,087,000	7,950,000
Industrial	2,905,571	8,210,000
Transportation	-	570,000
Electrical Generation	373,037	3,070,000
Total	4,365,608	19,800,000

1947 & 1976: Million cubic feet of gas used by consuming sectors in the U.S.

(Source: U.S. Bureau of Mines)

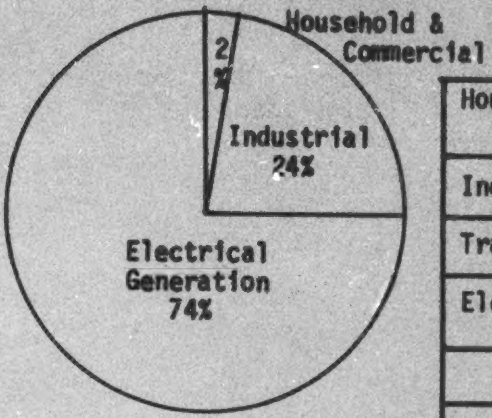
Coal

Used as a fuel for thousands of years, coal was the first fossil fuel applied to industrial purposes. It is a sedimentary rock consisting of altered remains of plants. Coal's quality depends on the amount of fixed carbon, moisture, and volatile substances it contains. Lignite is the lowest rank of coal, is brown, flaky and has the lowest heat value of all the coals. Bituminous coal or soft coal is black and is what is mined and used most frequently having a somewhat higher heat value. Anthracite is a very hard, high heat and cleanest burning of the coals, but is the least plentiful.

Of its 1976 energy mix, the U.S. consumed 18.6% of this in the form of coal, mostly bituminous coal. This is quite a drop from 1947 levels when coal made up nearly half of our energy consumed. From then on, coals' percentage decreased to a low in 1972 of 17.4%, however, rising again to the 1976 level of 18.6%. If President Carter's recent energy proposals become policy, coal's share will increased drastically in the next decade. The states most affected by this will be those with the largest bituminous coal reserves - West Virginia, Kentucky and, more and more, the western states.

Like natural gas, coal is primarily used as a fuel for energy generation. Space heating, high-temperature industrial processes and electricity generation are the main uses of coal in the U.S., the last of which consumed 74% of coal used in 1976. In 1947 it was not unusual for homes to use coal as their only source of heat nor was it unusual for 19% of the coal to be used for transportation purposes - specifically in the locomotive.[4] In recent decades, coal as a power source for electrical generation has increased monumentally.

In the U.S., coal is traditionally measured in short tons, one ton equal to 2000 pounds. In foreign countries coal is frequently measured in metric tons (2,204.6 lbs.) or long tons (2,240 lbs.). Varying with quality, the heat value of bituminous coal is on the average 26,200,000 BTU/short ton.[2]



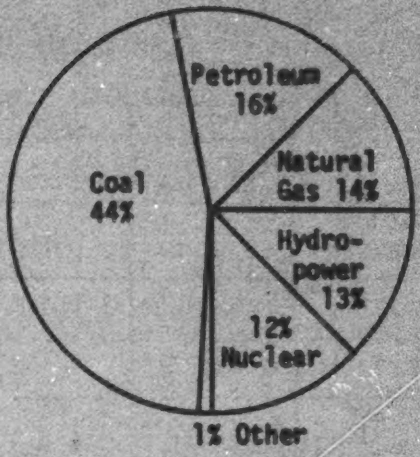
U.S. Coal Use
1976 Percent Consumed by Sector

	1947	1976
	(Thousand short tons)	
Household & Commercial	128,657	9,180
Industrial	273,403	145,428
Transportation	113,324	12
Electrical Generation	89,531	447,798
Total	605,443	602,418
1947 & 1976: Thousand short tons of coal used by consuming sector in the U.S.		

(Source: U.S. Bureau of Mines)

Uranium Ore

Depending on the type of nuclear reaction a power plant utilizes, uranium is or is not a depletable energy source from which the reaction develops. Converter or fission nuclear reactors which are now in operation depend on uranium-235, a high grade ore which at current rates of consumption will be depleted in 25 to 50 years. Uranium was first discovered in 1789 and occurs in some 50 minerals, most of them rare. The main ores are uranite and secondary minerals formed from it by weathering. Commercially available reserves of uranium are located primarily in the western states such Colorado, Utah, Arizona, Wyoming and New Mexico. Fission of one gram of uranium-235 is the energy equivalent of about 2.7 metric tons of coal or 13.7 barrels of crude oil. Nuclear power is used solely to generate electricity and in 1978 met 4% of total U.S. energy needs. The late 1950's saw nuclear power come into commercial use which now supplies approximately 12% of the energy utilized for U.S. electrical generation. Nuclear power is measured in generated kilowatt-hours. One kilowatt hour of electricity is generally equal to 3,413 BTU.



1978 Energy Consumption by Electric Utilities

(Source: U.S. Department of Energy-Energy Information Administration)

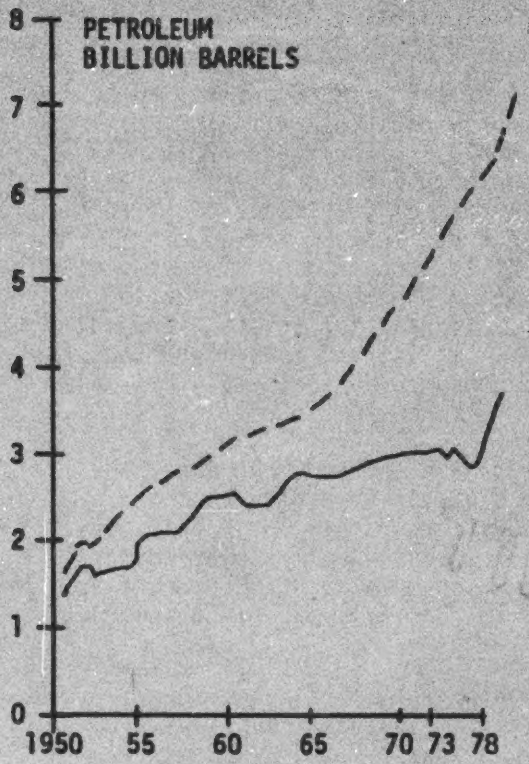
CASE for CONSERVATION

Demand vs. Supply

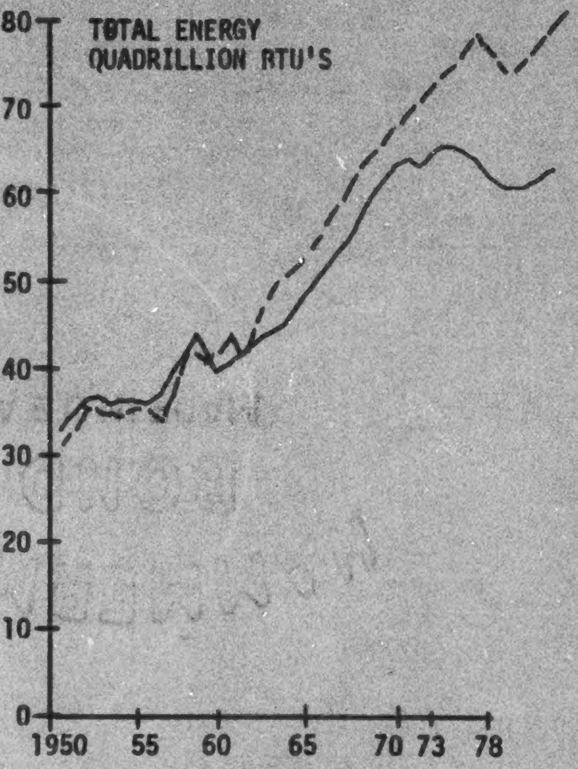
Historically, there appeared to be no end to the earth's resources of fossil fuels, minerals, timber, land, clean water and clean air. No thought was given to using any of it efficiently. However, as population grew, and the U.S. as an industrial nation evolved, more and more energy was used to supply the systems we developed for ourselves, some those which were very wasteful. Furthermore, greater and greater amounts of energy were required to develop resources including energy itself.

From 1950 to 1973, U.S. energy demand increased at an average annual growth rate of 3.5 percent, while domestic production of energy supply rose at just under 3 percent. In the eight years after 1965, demand raced ahead at 4.5 percent a year, while, since 1970, growth in domestic supply remained relatively constant. In 1978, domestic sources supplied 76% of demand while imported fuel made up the other 24%. An additional 2% of our domestic supply was exported, primarily in the form of coking coal, high sulphur coal and heavy oil, most of which have restricted use in the U.S.

The United States changed from being a net exporter of energy during the 1940's and part of the 1950's to become a net importer beginning consistently with 1958 when total domestic gross energy production was 94% of gross energy consumption. Over the next two decades, domestic energy production continued a downward trend. To make up the difference, we turned increasingly to foreign sources, particularly for our oil which had likewise become a greater part of our energy mix.[4]



U.S. Petroleum
Supply vs. Demand



U.S. Energy
Supply vs. Demand

——— Production ---- Consumption

Energy Consumption by Source in %	1950	1960	1970	1978
Coal	38.0%	22.8%	18.9%	18.1%
Petroleum	39.7	45.0	44.0	48.4
Natural Gas	18.1	28.5	32.8	85.4
Hydropower	4.2	3.7	4.0	4.0
Nuclear Power	-	-	0.3	3.8
Other	-	-	-	0.3
Petroleum Imports as a % of U.S. Petroleum Consumption	13.0	18.5	23.3	48.0

Source: U.S. Bureau of Mines

US and World Energy Use

The United States has been one of the greatest energy consuming nations for years. Overall U.S. energy consumption in 1978 was 78 Q BTU, 1.8 percent more than 1977 and 4.6 percent higher than in 1973, the previous record year. The growth between 1977 and 1978 was at a distinctly lower rate than that of the 1950's and 1960's when energy use increased 3-4 percent per year.[1]

However, U.S. growth in population when compared to world figures does not provide a logical rationale for this and indeed, points out U.S. energy wastefulness. It is hard to believe that the U.S., with 6% of world population, consumes approximately one-third of world energy used annually.

Data from several detailed studies also shows considerable variation in energy efficiency for a given range of per capita income. Sweden, West Germany and Switzerland have per capita incomes comparable to the U.S. but have substantially lower energy/output ratios. For example, Sweden uses only about 60 percent as much energy per capita as the U.S. but has a comparable standard of living.

There is no single factor which explains the higher U.S. energy/output ratio. But over half the difference is attributed to a higher energy intensiveness in three areas: passenger transport, residential space conditioning, and industry. Some of our relative inefficiency in passenger transport is probably due to our less dense living patterns, but the data also indicate that our automobiles are less efficient, and that we use less mass transportation. In the residential sector, when corrected for climate, less efficient heating practices combined with a preference for larger homes and single family dwellings account for a portion of the difference. A major source of the difference between the U.S. and Western Europe is that industry-for-industry the U.S. is considerably less efficient: on the average the U.S. uses more energy to produce a given amount of industrial material or product (e.g., steel) than Western Europe.

These international comparisons provide direct real-world evidence that U.S. energy requirements per unit of output can be reduced substantially over the longer run. Among industrialized countries, variations in per capita energy demands result largely from differing prices and policies, rather than differences in customs or income.[5]

Energy Conservation

As we have seen, the energy crisis is a result of numerous things, the most basic and obvious being that U.S. consumption has outpaced U.S. production, the latter which has remained relatively constant in recent years. Consequently, the U.S. turned increasingly to foreign sources of energy. Even then the energy crisis came to our attention only when the difference between U.S. demand and supply was not made up during the 1973 Arab oil embargo. After numerous government resolutions to nationally conserve energy, develop new resources and subsequently lessen foreign dependency, in 1979 the U.S. found itself again in a similar situation as it had in 1973, when the supply of oil from Iran was disrupted.

"Energy crisis" has become a household term, reflecting the awareness Americans have gained in recent years that the fuel supply we have traditionally been dependent on is depletable and foreign sources are disruptable. Citizens have come to recognize energy needs cannot and will not always be met in predictably familiar ways.

In this context of great uncertainty over future energy supplies, critical attention is being focused on the potential for energy conservation and improved energy efficiency. It is well recognized that the nation can get along using far less energy than it now consumes with no sacrifice in standard of living. Between 1973 and 1975, total U.S. energy consumption dipped by 5 percent as a result partly of the large increases in energy prices following the 1973 embargo and of the economic slow down of the mid-1970's. The fact that energy consumption rebounded by 7.5 percent between 1975 and 1977 and has continued to increase with the implied need for long-term increases in oil imports, is more than a little troubling.[6] It is apparent there will be no quick solution to the energy problem whether it comes in the form of newly found reserves of the familiar fossil fuels, or through the development of alternate energy resources.

In pursuing either of these avenues, the time span between research, development, actual implementation, public availability and acceptance will be great. Traditionally a change from one major energy source to another has required approximately 50 years. Conserving energy wisely can buy needed time by stretching our presently available fuels further.

One must realize that besides technical hurdles, there are also political, environmental and economic factors. Most estimates of the capital requirements for projected new energy sources range between $500 billion to one trillion by 1985. A barrel of oil saved makes more net energy available than a new barrel of oil produced because of the energy expended in producing energy. Therefore, a dollar invested in energy conservation is more valuable than a dollar invested in developing new energy resources. For example, ceiling insulation for a typical home in 1975 cost approximately $300 installed and would save an estimated 7 barrels of oil each year for the lifetime of the house. Using conservative estimates, the energy saved by the insulation is estimated to be the equivalent of 60 barrels of oil over the next 9-10 years.[7]

Thus, the 60 barrels of oil saved cost $300, or $5 per barrel. When compared to even 1975 heating oil prices of an average $16 per barrel, the ceiling insulation is dirt cheap. The same follows from comparisons with the 1975 cost of natural gas at $11/barrel equivalent and electricity as high as $35/barrel equivalent. In 1979, savings would probably be nearly double. Energy conservation makes economical sense at today's high fuel prices -- saving energy means saving money.

In terms of environmental pollution, energy conservation will minimize this danger by reducing the need for new production of additional fossil fuels. This will mean allowing more land to remain intact and undisturbed, fewer carcinogenic chemicals and particulates released to the air and water, and lesser quantities of radioactive waste to be disposed of. These are only a few of the tremendously important environmental and health benefits of energy conservation which are probably more important than most of us realize.

Conserving energy will stretch our fossil fuel base until substitutes are available or until we have developed new ways to meet our energy needs. It can be done without sacrificing our living standards. It can save us money and provide a healthier environment for ourselves and future generations. Energy conservation is a sincere, desirable national objective widely supported throughout the U.S. and world alike. However, the time has come to translate supportive words into supportive action.

CONSERVATION STRATEGIES

Sector Strategies

Sector specific conservation strategies strive to increase the efficiency of energy consumption within an individual consuming sector such as those we have discussed: transportation, household/commercial, industrial and electrical generation. Strategies within these sectors may be implemented through voluntary or regulatory approaches.

Voluntary programs are based on information dissemination and public education which provides the energy consumer with detailed information on how to implement cost effective energy conservation measures. Public information campaigns are also undertaken to overcome institutional, communication or other barriers which often prevent a sector from responding to conservation opportunities. The voluntary approach also includes the establishment of selected incentives for energy conservation such as tax credits for installing insulation in the home or may provide a framework in which energy conservation is more easy such as in van pooling programs or government weatherization programs.

On the other hand, regulatory strategies for energy conservation impose direct requirements on activities within an economic sector to assure more efficient use of energy. This may require such actions as installing special equipment or holding down temperatures. An example of a regulatory energy conservation strategy is the Energy Policy and Conservation Act of 1975 which set minimum fuel economy standards for 1978 model cars at 18 miles per gallon.

Pricing Strategies

Energy pricing strategies have wide-ranging implications and generally affect every sector of the economy encompassing the energy producers and the energy consumers. Energy pricing strategies are based on the principles of supply and demand in the marketplace. A particular strategy may affect consumer demand and consequent supply depending on the price people are able or willing to pay. The amount of capital generated or not generated in an energy industry by a particular pricing strategy in turn affects the future search for and development of a particular fuel. For example, the proposed phased deregulation of natural gas is hoped to encourage resource development of that fuel as a result of higher prices. With more money flowing into the natural gas industry, more money will be available for costly drilling and exploration. However, the deregulated price of natural gas could go prohibitively high for many consumers and, therefore, deter activity in resource development.

Combined Strategies

A combination of sector-specific and energy pricing strategies may be a more appropriate energy conservation approach. The combined strategy is generally oriented toward restructuring basic energy consumption and production patterns in order to achieve particular energy goals. For example, the goals of reduced U.S. dependence on foreign oil, increased energy efficiency and expanded development of domestic oil reserves could include the combined strategies of oil import quotas on the U.S. petroleum industry, mandatory maximum and minimum building temperatures in or or all sectors and deregulated oil prices affecting all sectors.

SECTOR CONSUMPTION and CONSERVATION STRATEGIES

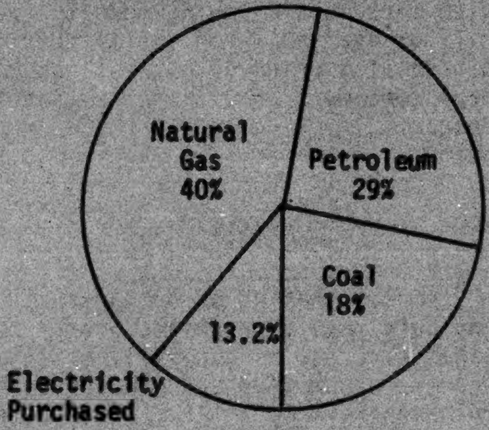
There are a number of conservation measures that are economically and technically possible today and in the future. The potential for fuel conservation is reviewed here for each of the major consuming sectors based on conclusions by the President's Council on Environmental Quality. In the CEQ's words, "Our overall conclusion is that the United States can do well, indeed prosper, on much less energy than has been commonly supposed. The principal basis for this good news is the accumulating evidence that the means are available to wring far more consumer goods and services out of each unit of fuel that we use, whether it be a barrel of oil or a ton of coal or uranium."5

INDUSTRIAL SECTOR

Energy Consumption

The industrial sector is made up of construction, manufacturing, agriculture and mining establishments. In 1977, industry used 37.0% of all energy consumed in the U.S. for that year. About half of that energy went for heating processes, either through direct burning of fuels or through the manufacture of steam. Much of the rest was used for running machinery, electrolysis, lighting and for non-fuel use purposes--that is as raw materials or feedstocks for manufacturing processes. Approximately 75% of the energy consumed by this sector was used by the 10 most energy-consumptive industries listed below.

Food and kindred products
Textile mill products
Paper & allied products
Chemicals & allied products
Petroleum & coal products
Stone, clay & glass products
Primary metals
Fabricated metals
Machinery, except electric
Transportation equipment



1976
Industrial Demand for Energy by Source

Conservation Measures

The clearest evidence of a genuine shift toward conservation has been in industry. This fact emphasizes how wasteful these large scale industries have been. In 1977 despite a 5.6% increase in production, energy use declined by 0.1% from the 1976 level. By way of comparison, industrial energy demand in the 1960's grew approximately 3.5% per year. The combination of increased industrial output with level energy consumption results largely from continued improvements in efficiency.

As a result of the Energy Policy & Conservation Act of 1975, nearly all industries are required to report on their energy efficiency to the Department of Energy. Based on an estimate from these reports, energy efficiency for the first half of 1977 was projected to be about 9.3 percent above the 1972 base level. The annual savings yielded by the improvement amounted to about 1.4 quadrillion BTU, which is the equivalent of 7% of the nation's current level of natural gas consumption, 11% of coal use, 44% of hydropower and geothermal demand or 85% of nuclear power generation. Substantial reductions are obviously possible in this sector.[5]

Potential Annual Fuel Savings in the Industrial Sector

(% of 1973 total energy demand)

Conservation Measures	Potential Savings
Good housekeeping measures throughout industry	5.2
Fuel instead of electric heat in direct heat applications	0.2
Steam/electric cogeneration for 50 percent of process steam	3.5
Heat recuperators or regenerators in 50 percent of direct heat applications	1.0
Electricity from bottoming cycles in 50 percent of direct heat applications	0.7
Recycling of aluminum in urban refuse	0.1
Recycling of iron and steel in urban refuse	0.1
Fuel from organic wastes in urban refuse	0.9
Reduced throughput at oil refineries	1.2
Reduce field and transport losses associated with reduced use of natural gas	1.1
Total	14.0*

*Totals may not add due to rounding.

Source: Adapted from M.H. Ross and R.H. Williams, "Energy and Economic Growth," published in Achieving the Goals of the Employment Act of 1946--Thirtieth Anniversary Review (Washington, D.C.: U.S. Government Printing Office, 1977).

According to the Council on Environmental Quality, industrial energy demand in 1973 could have been reduced by about 30 percent through several specific changes including:

- Improve management and "housekeeping" practices with little or no changes in capital equipment. Examples of such improvements include adjusting temperatures for space heating and cooling, turning off unnecessary lighting, shutting down machines when not actually being used, repairing steam leaks, cleaning heat transfer barriers, and maintaining steam traps and boilers at peak efficiency.

- Produce 50 percent of the process steam through the cogeneration of steam and electricity, and generate electricity with bottoming cycles. Cogeneration can reduce by roughly 30 percent the amount of fuel required to separately generate the same amount of electric power and steam if done separately.

- Add heat recuperators or regenerators in one-half the direct heat applications.

- Reduce processing and transportation losses associated with energy conversion and transmission. In the near future electricity, for example, could be generated more efficiently with fuel cells, and transmission losses could be reduced by locating generation facilities closer to load centers or improving transmission lines.

- Recycle the steel, aluminum, paper and rubber in urban refuse and use its organic material for fuel.

These are only a few of the more obvious improvements. Others include the substitution of more efficient electric motors, the replacement of obsolete plants and facilities, and the development of new basic processes or technologies.

Clearly, it will require time to improve or replace existing equipment and procedures, but over a period of two or three decades, incremental changes can lead to dramatic improvements.[5]

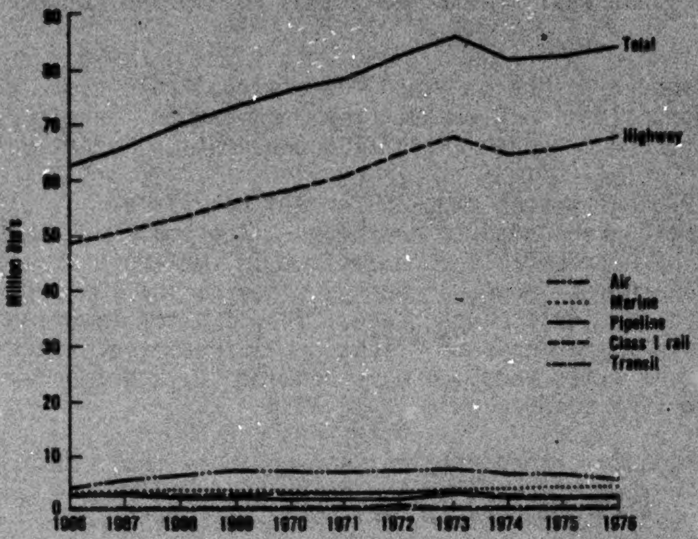
TRANSPORTATION SECTOR

Energy Consumption

Accounting for 55% of 1976 petroleum consumption, this sector consists of both private and public passenger and freight transportation, as well as government transportation, including military operations. Growth has been the outstanding trend in energy use for transportation. Today, slightly over 26% of the total annual energy consumed in the U.S. is by the transportation sector. From 1965 through 1973 per capita consumption steadily increased at an average annual rate of more than 4%.

Highways continued to dominate the other four transportation modes (air, rail, marine, and pipeline) and accounted for 81% of transportation energy consumption in 1976. Transportation relies on petroleum to meet over 95% of its energy demand, while the highway mode is almost exclusively dependent on petroleum.

Per Capita Energy Use by Transportation 1966-76



Source: William F. Gay, *National Transportation Statistics*, DOT-TSC-OST-77-68 (Washington, D.C.: U.S. Government Printing Office, 1977), p. 82.

Energy Use on Highways					
	1972	1973	1974	1975	1976
Vehicle miles traveled (billions)	1,265	1,316	1,283	1,330	1,409
Highway motor fuel (million gallons)	105,062	110,473	106,301	108,984	115,700
Gasoline (million gallons)	96,543	100,636	96,505	99,354	104,978
Average miles per gallon of motor fuel	12.0	11.9	12.1	12.2	12.2

Source: U.S. Department of Transportation, Federal Highway Administration, Highway Statistics, annual (Washington, D.C.: U.S. Government Printing Office, 1972-77).

In 1973-74 the energy use trend in transportation reversed. It declined absolutely in 1974 and barely rose in 1975. Several factors contributed to the reversal. Not only was petroleum in short supply during the oil embargo of 1973-74, but prices jumped. Simultaneously, real incomes and real GNP declined, reinforcing the negative impact of increased prices.

Additional impetus for reducing energy consumption came from government conservation policies and programs. Among them were speed limits of 55 miles per hour, encouragement to carpool and use public transit, and consumer education regarding new car fuel efficiency.

And, mentioned earlier, an important measure whose impact is only beginning to be realized is the Energy Policy and Conservation Act of 1975.

All these factors combined for a significant drop in energy use in transportation. But whether the decrease is transitory or it signals a trend in conservation and consumption is not yet clear.

In 1976 energy consumption for all but air and pipeline transportation rebounded to new highs. The small decline for pipelines may be attributable to a decline in the amount transported. In air, government-sponsored energy conservation measures have clearly made a significant change. They include lowering cruising speeds and eliminating some flights to increase load factors; the percentage of seats occupied on scheduled flights improved from 53.7 percent in 1975 to 55.4 percent in 1976.

For highway transportation, surveys show that consumers have adopted a number of conservation measures-reducing the number of trips, carpooling, and buying more fuel-efficient vehicles. In several cities, most notably Los Angeles, Houston, Minneapolis, and Knoxville, efforts to organize vanpools and carpools have met with considerable success. The number of vanpools has doubled each year for the last 5 years.

Nonetheless, as the Figures indicate, the immediate postembargo decline in per capita energy use in highway transportation was short lived. In fact, growth of the total transportation energy demand resumed largely because of renewed demands for highway fuel. Only the significant savings in air kept the combined per capita energy use for transportation in 1976 below the preembargo high. Preliminary data for 1977 indicate a 2.8 percent per capita increase in highway energy consumption.

Conservation Measures

The evidence in the transportation sector is sufficient to suggest that the dip in energy use in 1974-75 came about largely in response to price increases and economic recession and that consumption promptly rose when prices stabilized and economic growth recommenced. Encouragement by government and voluntary compliance by individual drivers appear to have had only a brief effect. However, there are indications that government requirements for energy saving practices in regulated industries and for energy-saving construction of motor vehicles hold promise for lasting conservation effects.[6]

In fact, cost-effective energy savings in the transportation sector of up to 50 percent are possible. Given enough time for a changeover, these savings could be achieved with a relatively small increase in purchase costs which would be more than offset through savings in fuel costs. These savings could be accomplished by using existing technology to improve auto fuel economy by 150 percent. Obvious measures to improve automobile fuel economy include:

- Emphasize smaller light-weight vehicles. The greater use of light-weight materials and the adoption of new designs which reduce the amount of material needed for a fixed interior size have already reduced the weight of some models by several hundred pounds. To a first approximation, automobile fuel economy is inversely related to vehicle weight: the lighter the car, the farther it will go on a gallon of gas. Over the longer term, automobile weights can continue to be reduced through the use of advanced composite materials.

- Improve the efficiency of the drive train. Options include the greater use of manual transmissions, the use of improved torque converters with lock-up and overdrive features, and the substitution of continuously-variable transmissions.

- Reduce rolling resistance through the substitution of improved tires. The use of radial tires in place of bias ply or belted bias tires can increase fuel economy by several percent.

- Improve vehicle aerodynamics by streamlining automobile designs to reduce air drag greatly.

- Improve engine efficiency through design modifications to the conventional Otto engine, or by greater use of alternative engines, such as Diesel and Stirling cycle power plants.

- Improve the operating efficiency of automobile accessories.

Increased energy productivity by airlines depends on continued R&D and the purchase of new, more efficient aircraft. Technical improvements include the use of more efficient propulsion systems, the application of more efficient aerodynamic designs, and improved aircraft structures. These modifications could lead to an overall improvement of 25 percent or more in aircraft efficiency by the end of the century. Load-factor increases could provide further efficiencies in air travel.

Improvements in freight efficiency are possible through the widespread adoption of diesels by the truck fleets and through drag reduction. Over the long term, the overall improvement in truck efficiency could be up to 50 percent. Some modal shifts from trucks to the less energy intensive rail system would help to limit transportation energy requirements.

Additional energy savings could be achieved by encouraging the wider use of cost-effective mass transit in major urban areas. Efforts would be required to apply innovative concepts to increase the convenience and versatility of urban mass transit systems. Carpooling and driver behavior improvements can also add to energy saving.[5]

RESIDENTIAL and Commercial Sectors

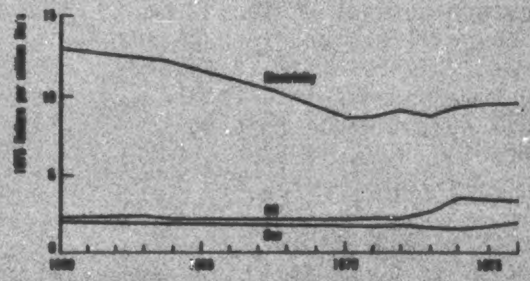
Energy Consumption

These sectors consist of housing units, non-manufacturing business establishments (e.g. wholesale and retail businesses), health and educational institutions, and government office buildings. The overall trend in residential and commercial energy use from 1960 to 1977 was growth. Consuming 38% of the nation's energy budget in 1978, the primary applications are for space heating and cooling, lighting, water heating, and operation of small appliances.

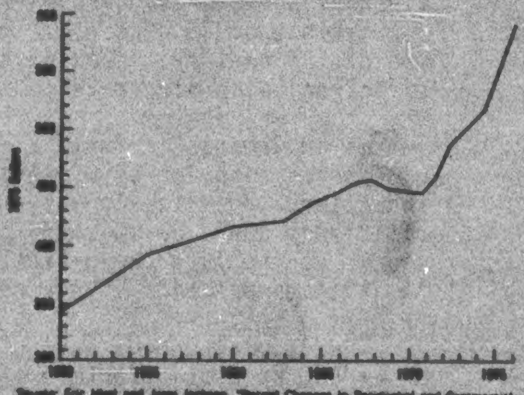
Between 1960 and 1972, energy use in buildings grew at an average annual rate of 5 percent. Commercial use grew at over 6 percent per year and residential was under 5 percent. In 1973 energy use trends varied erractically from the pattern of steady increase, with no overall growth through 1975. In 1976 growth resumed at its former rate of 5 percent and continued at the same rate in 1977.

Changes in residential and commercial energy consumption roughly paralleled the rise and fall of economic activity in the 1970's and rising energy prices in the residential sector coincided with the leveling off of consumption. Trends in energy expenditures per household underscore the point. As expenditures for energy rose, household energy consumption declined. In 1976, as price increases continued but at a more moderate rate, consumption per household again turned upward. The same trends are apparent in commercial fuel expenditures.

Average Residential Energy Prices 1960-76



Per Household Energy Expenditures 1950-76



Source: Eric Hirst and Jerry Jackson, "Recent Changes in Residential and Commercial Buildings," Oak Ridge National Laboratory, February 1978.

During the last two decades, the mix of fuels supplying the energy shifted markedly. Electricity's share in the residential sector increased from 26% in 1960 to 46% in 1976, gas declined from 37% to 32%, oil from 26% to 18%, and other fuels - such as coal and propane - declined from 11% to 4%. Similar shifts in fuel choice occurred in the commercial sector. Several factors were important in the shifts: energetic marketing of electricity by utilities, public perception of gas and electricity as cleaner and more convenient than oil, population shifts away from New England where oil is heavily used, shortages of natural gas in the 1970's and onward, and fuel price changes.[6]

Today, office buildings use far more energy, on the average, than do older buildings with an equivalent amount of space. The difference can be traced frequently to building design--hermetically sealed windows create the need for mechanical heating and cooling on days when simple ventilation would provide comfortable indoor temperatures; glass walls add to building heating and cooling requirements because they allow high levels of heat loss and heat gain; and office spaces without any windows require artificial lighting when natural light, if available, would be ample. Furthermore, today's businesses rely on a proliferation of office machines, computers, elevators and escalators.

Convenience and comfort appliances led the growth in household energy consumption in the decade of the 1960's which included air conditioners, clothes dryers, and television. According to the Ford Foundation's Energy Policy Project (study of energy use and lifestyles) almost all American homes now contain five basic energy-consuming items: central heat, hot water heater, stove, refrigerator, and electric lights. Virtually all have one radio and one television as well. Seven out of ten have washing machines. Central air conditioning systems for example, grew from five percent of American households having these systems in 1969 to 15 percent in 1973. Possession of dishwashers increased from six percent to existing within 25 percent of all households during the same period. Clothes dryers, which existed in less than one-fifth of American households in 1960, were found in almost half by 1973.[7]

In some cases, household energy growth has been further stimulated by design changes that diminish the efficiency of energy use. Most refrigerators currently marketed are large, frost-free models requiring about two-thirds more energy per unit than smaller, more economical models with manual defrost. Color televisions typically consume almost half again as much electric power as black and white sets. Sometimes greater energy demand in one area affects demand in other energy sectors as well. For example, dishwashers and automatic washing machines not only use electricity, but require even additional energy for hot water heating.

Residential energy consumption levels are frequently influenced by decisions in which an individual home owner has a little to say. Refrigerators, dishwashers, air conditioners, and hot water heaters are often chosen by the builder, or by the previous homeowner. Home heating systems are replaced less often than most appliances making it even less likely that a current fuel consumer participated in the choice of system for his home. One-fifth of all American households (mostly apartment dwellers) have no control over their thermostat settings. Such residents can exert direct control over their dwelling temperatures only by opening windows or turning on portable electric heaters or blankets. This can add still more to their energy consumption.

Furthermore, the trend toward built-in, energy-consuming features in new homes has grown in the last few years. Builders are incorporating electric heating systems and central air conditioning in an increasing number of homes and apartments, and concrete slab construction without insulation from the cold ground is becoming more common. Overall home design has become less and less oriented toward energy efficiency.

Conservation Measures

It does appear, however, that energy conservation is on the rise in many households and commercial buildings. Industry data show that 2-3 million households added an average of 4-5 inches of attic insulation during 1974, 1975, and 1976. Reports in 1977 suggest a figure of nearly 6 million. Adding 4-5 inches of attic insulation cuts space heating needs by 10-20 percent, depending on local climate and the condition of the house.

Occupants of 10 million single family detached homes (22 percent of the applicable housing stock) took action to add energy-saving features in 1975. The average household spent $150 for attic insulation, wall insulation, storm doors, storm windows, caulking, and/or weatherstripping.

The number of new heat pumps installed in homes increased rapidly from 61,000 in 1971 to 250,000 in 1976, doubling between 1975 and 1976. Heat pumps provide winter heating with approximately 60 percent of the electrical energy required by electric resistance systems. This increase in sales is particularly significant because the initial investment is several hundred dollars more than for a conventional system supplying electric resistance heat and central air conditioning.

There are many examples of individual schools, hospitals, and stores whose "housekeeping" changes have produced large energy savings. A large office building in Los Angeles, for example, cut energy use 45 percent with lower lighting levels, lower thermostat settings for winter and higher ones for summer, and improved controls on heating-cooling ventilation systems.

It is very difficult to determine to what extent federal policies have effected these changes and how much they resulted from fuel price increases or threatened shortages. It seems likely that so far federal policies have had relatively little effect on conservation in buildings. An important exception is the Federal Energy Management Program, which has achieved impressive savings in the operation of federal buildings. Primarily through housekeeping changes, energy use in federal buildings dropped 20 percent between 1973 and 1975.

Potential Annual Fuel Savings in the Residential Sector
(percent of 1973 total energy demand)

Conservation Measures	Potential Savings
Replace resistive heating with heat pumps	0.8
Increase air-conditioner efficiency	0.5
Increase refrigerator efficiency	0.4
Cut water heating fuel requirements	1.4
Reduce heat losses	4.4
Reduce air conditioner load by reducing infiltration	0.6
Introduce total energy systems into 1/2 multifamily units	0.4
Use microwave ovens for 1/2 of cooking	0.3
Total	8.8*

Potential Annual Fuel Savings in the Commercial Sector
(percent of 1973 total energy demand)

Conservation Measures	Potential Savings
Increase air-conditioner efficiency	0.5
Increase refrigeration efficiency	0.3
Cut water heating fuel requirements	0.4
Reduce building lighting energy	1.3
Reduce heating requirements	3.0
Reduce air-conditioner demand with better insulation	0.1
Reduce air-conditioning demand by reducing ventilation rate and by using heat recovery apparatus	0.1
Use total energy systems in 1/3 of all units	0.9
Use microwave ovens for 1/2 of cooking	0.1
Total	6.6*

*Totals may not add due to rounding

Source: Adapted from M.H. Ross and R.H. Williams, "Energy and Economic Growth," published in *Achieving the Goals of the Employment Act of 1946--Thirtieth Anniversary Review* (Washington, D.C.: U.S. Government Printing Office, 1977).

Federal programs may well have major impacts on energy use in buildings in the future. For example, the Department of Energy has set efficiency targets for appliances to be effective in 1980, and the Departments of Energy and of Housing and Urban Development are developing thermal standards for new buildings started after 1980. Other government programs are designed to provide information, encouragement, and financial incentives to owners and operators of residential and commercial buildings to upgrade existing buildings and improve the efficiency of operation.[6]

Technical changes in the residential/commercial sector could lead to a more than 40 percent reduction in its fuel requirements. A careful look at the energy actually used by homes and commercial buildings in 1973 suggests a wide array of specific opportunities for energy efficiency improvements. The more important technical improvements include:

- Reduce heating losses by 50 percent with better insulation, improved windows and reduced infiltration; this reduction is the single most important step in this sector accounting for about one-half of the savings.
- Substitute heat pumps for electric resistance heating.
- Cut water heating fuel requirements by 50 percent through the addition of more insulation, reduced hot water temperature settings, and the use of solar energy or heat recovery from other appliances.
- Increase the efficiency of new air conditioners and refrigerators, and introduce total energy systems.
- Improve lighting systems to reduce energy requirements for lighting in commercial buildings by 50 percent.

The possibility of making these improvements has been well documented. For example, it has been shown that energy consumption by refrigerators and air conditioners varies over a remarkably wide range. In the case of refrigerators energy use can vary by a factor of two within a single class of size and features with little correlation between energy requirements and first cost. In addition to the opportunities for more efficient appliances and space heating systems, the energy characteristics of most buildings themselves can be vastly improved. New buildings can be economically designed to reduce typical space heating requirements by 75 percent, with similar savings achievable in many older buildings.

Attic and wall insulation can be increased. Storm windows, storm doors, and weatherstripping can be added. The efficiency of heating and cooling can be raised through the increased use of heat pumps instead of electric resistance heating and by the substitution of improved air conditioners and oil and gas furnaces. And new homes can be built with many "passive solar" features such as overhangs, large southern exposures, and moveable insulated window panels.[5]

These are only a few of the conservation strategies available to homeowners. It is the primary purpose of this manual to treat each of these and additional strategies in detail.

U.S. ENERGY in the FUTURE

Alternative Resources

More and more one hears of alternative energy sources, nonconventional energy sources, synthetic fuels and renewable energy sources. Clarification of these phrases and an assessment of just how much we can realistically expect from these energy sources in the future is necessary.

The common characteristic of all these phrases is that they connote a difference from fuels we have traditionally or conventionally used--thus, the terms "non-conventional" and "alternate" energy. Traditional or conventional U.S. energy has been based primarily on fossil fuels--coal, petroleum and natural gas--and more recently on the non-fossil fuels of nuclear and large-scale hydroelectric power. From here, the meaning of alternate energy diverges into two kinds: 1) Synthetically derived energy still based on fossil fuels and the current energy grid, and 2) energy derived from non-fossil fuels which could be used on a decentralized, individual site basis.

FOSSIL FUELS	
Conventional	Non-conventional
• oil • natural gas • petroleum	• synthetic fuels coal gasification coal liquefaction oil from oil shale oil from tar sands
NON FOSSIL FUELS	
Conventional	Non-conventional
• nuclear • hydroelectric	• geothermal • renewable energy flows solar ocean tides and currents wind biofuels: alcohol, methane & other fuels from organic wastes

The diagram above can help clarify how most of these alternate energy sources are classified. There is some difficulty in categorizing various sources. For example, gasohol is based partly on fossil fuel and partly on non-fossil fuel. The alcohol is distilled from plant matter (e.g. corn plants) but is added to gasoline a petroleum product, to make gasohol. Furthermore, hydropower could be thought of as non-conventional when used on a small-scale with individually owned streams for on-site use of electricity as opposed to the conventional, large-scale flooding for electrical generation to power cities miles away. However, the above framework can still provide a base for understanding. Renewable and non-renewable energy are two other terms currently heard. Strict definitions of each are, again, difficult. All resources can be renewable if given billions of undisturbed years and necessary conditions. Therefore, it is the element of time which defines renewable and non-renewable. At one extreme is solar power which is continually renewing and is a resource which will probably exist as long as the earth does. At the other extreme is petroleum reserves of which we could potentially see come to an end in our lifetime. The term "solar power" is sometimes used to mean all the renewable energy flows including also wind, ocean tides, and biofuels. The reason for this is because the sun plays a direct role in each. For example, plants exist because of photosynthesis, a direct reaction to the sun.

FUTURE ENERGY FORECASTS

Forecasts are educated guesses about the future based on what we know about the present and past. As with any kind of forecast, energy forecasts are tricky and based on assumptions. Different assumptions result in different forecasts. Most energy forecasts make assumptions about what the future of the following will be and then make their energy assessments:

1. government policy
    - environmental standards
    - energy plans

2. state of the economy

3. energy prices

4. oil imports and disruption in supply

5. conservation and consumption patterns

Common sense tells us that no one forecast will be exactly correct and that a particular energy scenario for the future can oftentimes be biased toward one thing or another due to a vested interest or orientation. For example, oil companies may forecast that solar power really won't have much impact on lowering our future energy demand. One can make his own conclusions as to any bias this particular industry might have.

With these thoughts in mind, a brief overview of what various groups are saying about the future energy picture follows.

In the years prior to the 1973 oil embargo, most U.S. energy studies projected continued rapid growth in energy based on historical trends. But the embargo years saw traditional patterns of energy usage and supply disrupted and the American people proved they could conserve energy when they had to. Since then, estimates of energy needs and requirements have changed dramatically. As a rule of thumb, the older the study, the higher the energy demand forecasts.

Many studies explore and forecast the feasibility of low energy demand levels at the end of the century and beyond. These studies have been done by groups such as the National Academy of Sciences, the Oak Ridge Associated Universities' Institute for Energy Analysis, and the Ford Foundation's Energy Policy Project. Each one points to the very real possibility of a low energy growth future very different from historical trends and yet still accompanied by an economy with steadily rising GNP.

A 1977 study done for the Joint Economic Committee concluded that:

- Technical improvements in today's economy could eventually lead to an estimated 40 percent reduction in fuel consumption with a net effect of zero growth in energy consumption from 1985 to 2000.
- An expanded effort to increase energy productivity would create many new job opportunities and encourage productivity gains in the economy.

The most recent detailed look at the possibility of a low energy growth future was published in 1978 by the Demand and Conservation Panel of the National Academy of Sciences' Committee on Nuclear and Alternative Energy Systems (CONAES). Given time for the economy to respond, the analysis concluded that a "major slowdown in demand growth can be achieved simultaneously with a significant economic growth by substituting technological sophistication for energy consumption." More specifically, the study found that energy demand in the year 2010 could be roughly the same as today's level while providing a higher level of amenities, even with a total population increase of 35 percent. The study also determined that even if real energy prices were to stay at about their present level, growth in energy demand would be considerably slower than most past projections have indicated.[5]

Exxon Corporation, the major oil company, also makes energy predictions. In their most recent forecast, Energy Outlook, 1978 - 1990, Exxon concluded that "conservation efforts are projected to achieve a demand reduction equivalent to 17 million barrels per day or a 25% reduction by 1990." However, the report, in contrast to the conclusions of those mentioned above, Exxon goes on to say "Energy conservation is an important goal, but it must not be regarded as the whole answer to the nation's energy problems. There are practical limits to conservation beyond which there will be adverse impacts on economic growth, job opportunities, and standard of living. Even assuming substantial conservation measures, U.S. energy demand in 1990 will be more than one-third higher than today. Significantly reducing U.S. import dependence will thus require aggressive development of U.S. energy resources in conjunction with energy conservation." Directly in conflict, the CONAES study above concluded that energy demand in the year 2010, 20 years later than Exxon's outlook, could be about the same as today's.

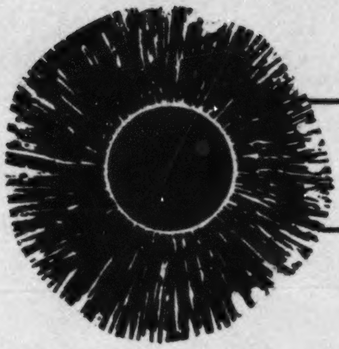
As far as what fuels will contribute to our future energy supply, Exxon states that "oil will remain the predominant fuel through 1990, although its share of total energy demand will decline. Limited availability of gas will require other energy sources, particularly oil and coal, be used to meet a growing share of U.S. fuel needs. Gas'share of total energy demand will decline steadily over the forecast period. U.S. coal production is expected to more than double from 1977 to 1990. Electric utility and industrial coal use is projected to increase rapidly over the outlook period, primarily due to economic fuel selection. U.S. coal resources, as well as the capability to develop them are more than adequate to meet projected demand, assuming reasonable coal mining regulations. Nuclear energy is confined to electric utility use. Although its development continues to be marked by construction, regulatory and siting delays, nuclear energy is expected to supply 10% of total U.S. energy demand by 1990, compared with 3% in 1977." Exxon's assessment of solar power's development is not very positive. Solar is lumped together with hydropower and geothermal, and the three sources combined, are expected to supply only 3-4% of total U.S. energy requirements over the outlook period. "Hydro and geothermal have small growth potential due primarily to limited site availability. Solar is a promising energy source over the long term. Solar's most probable near-term applications are water and space heating, but its contribution in these areas through 1990 is projected to be limited by high initial costs and practical considerations as to how fast it can be brought into wide use. Achieving solar's potential will require a substantial effort to reduce current costs and to establish the solar support industry necessary for long-term growth."

In disagreement with Exxon's limited assessment of solar are many studies including the President's Council on Environmental Qualities' report Solar Energy: Progress and Promise and a report by the congressional Office of Technology Assessment entitled Application of Solar Technology to Today's Energy Needs. The Councils' report concluded that the nation could meet as much as one-quarter of its energy demands from solar sources by the end of the century and perhaps as much as one-half by the year 2020. Other basic conclusions of the report were: First, solar energy is already a serious option with some applications at or near commercial feasibility. They include passive solar heating, the burning of forest wastes for industrial use, solar hot water heating, electric power generation at existing small hydro dams, and power generation at remote sites using photovoltaic cells. Second, if the nation today makes a strong national commitment both to accelerated solar energy use and to energy conservation, it should be possible to meet up to a quarter of its energy needs by the year 2000. Further, for the period 2020 and beyond it is possible to speak of the United States' becoming a solar society--one in which solar is not a supplementary source but rather a primary source of energy.

The report Application of Solar Technology to Today's Energy Needs by the Office of Technology Assessment analyzed the prospects of "onsite" solar technology designed to be located on or near the buildings or groups of buildings for which they are to provide heat or electricity. The study concluded that the technical feasibility of most direct onsite solar energy systems has been experimentally established. Moreover, by the mid-1980's, the range of cost which can be reasonably forecast for energy from these on-site devices will overlap the range of costs forecast for conventional sources for many applications. The report stated that with aggressive federal support, onsite solar technologies could indeed be made economically competitive in markets representing 40% of U.S. energy demand by the mid-1980's. The study also noted that solar technologies are uniquely disadvantaged at this time because of federal programs that control fuel prices and otherwise subsidize nonsolar energy sources.[6]

These studies illustrate the varying conclusions that can be reached from different assumptions and predispositions. One must try to weigh the results of each with one's own knowledge of the energy situation, and consider the credibility of the source. Whatever the forecast, the American people will determine the energy future of this country by making individual decisions to conserve energy, use it wisely and, from there, decide what direction they want America to take.

unit 2



HEAT TRANSFER

by: M.P. Vogel

There is more to home energy conservation than just stuffing insulation between joists in the attic, caulking, and weatherstripping doors and windows. Before various conservation techniques are started and before the proper heating or cooling loads can be determined, heat loss calculations are required. In order to better understand the requirements and methods for control of heat, it is necessary to know basic facts and terms used in these calculations. The following information gives a good background for determining design requirements for effective thermal control.

Home Energy Conservation Primer

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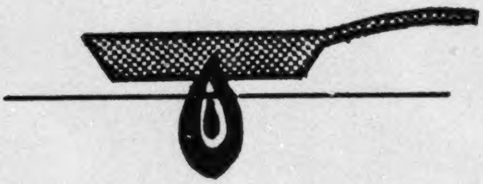
HEAT

Heat results from the vibration of molecules of any substance. The more rapidly the molecules vibrate, the higher the temperature. Therefore, heat can be defined as a form of energy. Temperature is the intensity, not the quantity of heat.

Heat energy always flows from a warm material, body, or space to a cooler material, body, or space. For example, a building heated to 72°F will lose heat to the outside when the temperature there is lower than 72°F. In winter, heat flows from the warm interior of a house to cooler exterior; this is referred to as "heat loss." In summer, heat flows from the warmer exterior to the cooler interior of a house; this is called "heat gain." During such movement, heat will travel by one or a combination of these methods: (a) conduction; (b) convection; (c) radiation.

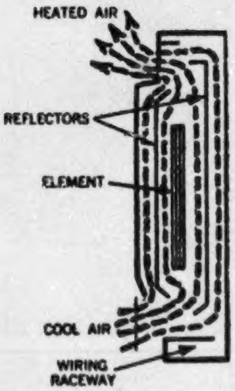
Conduction is the transfer of heat from one part of a body to another part of the same body without any relative displacement of the parts of the body. The faster moving molecules in the body creating the most heat give off energy in the adjoining slower moving molecules which in turn move faster. This process will continue until all molecules in the body or adjoining bodies are vibrating at the same rate which implies that they will have the same temperature. An example of this would be heat applied to a skillet sitting on a hot stove. (See Figure 2a).



CONDUCTION

Figure 2a

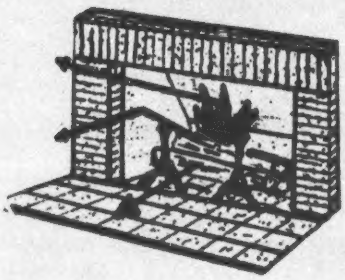
Convection is the movement of air and heat caused by warm air rising and cold air sinking. In this way, heat is transferred by the actual physical movement of air. This method would apply to warm air rising in a convection furnace system, or movement of air over a hot surface such as a radiator, or heating elements. (See Figure 2b).



CONVECTION

Figure 2b

Radiation refers to the transfer of heat through space by wave motion. The heat source emits radiant energy which travels to a surface having a lower temperature. An example would be energy in the form of infrared rays transferred through the air and transparent materials from one place to another such as from sun to earth, or from the fire in a fireplace to persons or objects in the room. (See Figure 2c).



RADIATION

Figure 2c

PATHS OF HEAT LOSS/GAIN

There are five general paths of heat loss from a house which must be considered when planning heating and cooling systems and/or weatherizing.

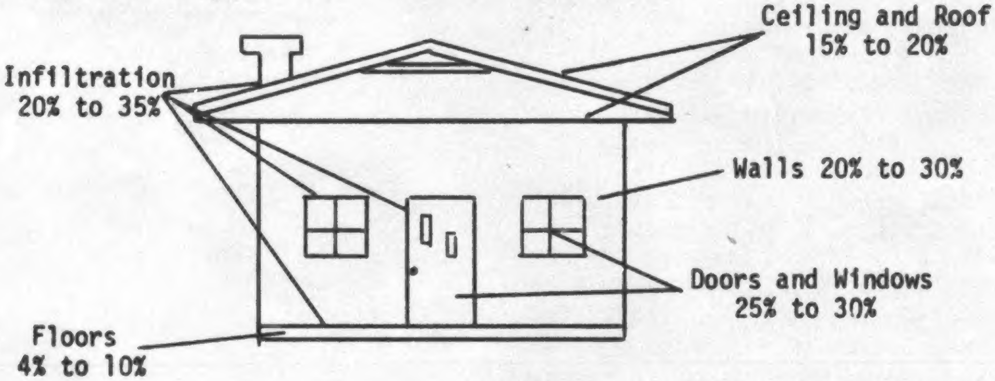


Figure 2.D Paths of Heat Loss

1. CEILING AND ROOF: Where from 15% to 20% of total heat is lost. This can be reduced by proper insulation and ventilation.
2. DOORS AND WINDOWS: Where about 25% - 30% is lost. Storm windows, storm doors, and insulated shutters can reduce this loss.
3. WALLS: From 20% to 30% of heat is lost through walls. Proper insulation can reduce this loss.
4. FLOORS: Only 4% to 10% of heat is lost through floors over unheated spaces, but this loss is considerable when planning insulation.

5. INFILTRATION OR AIR CHANGES: One or two air changes per hour are necessary to move stale air in the home, however, more air changes than this can cause an estimated 20% to 35% of the heat loss. Infiltration is the passage of air from outdoors, into a residence through a variety of openings (doors, windows, cracks, vents, dampers, etc.). Exfiltration is the passage of air out of a residence via the same matter as infiltration. Too much infiltration and exfiltration results in an unnecessarily high rate of air change. Practices such as weatherstripping and caulking around doors and windows, and not opening doors unnecessarily in the winter and summer can reduce these losses considerably.

THERMAL RESISTANCE VALUES

BTU - In calculating the heat loss of a building, the unit of heat measure known as the British Thermal Unit (BTU) is used. In any discussion of heat loss or insulation values, the BTU is the unit of measure for the quantity of heat. One BTU is the amount of energy required to raise the temperature of one pound of water 1°F. One BTU is approximately equal to the amount of heat produced by a wooden match.

"U" FACTOR - To make the heat unit applicable for determining the relative insulation values of various materials, a coefficient of transmission, commonly designated as the "U" factor is used. "U" factor is the amount of heat expressed in BTUs that will pass through a combination of materials and air spaces such as the construction of a roof, a ceiling, a floor, or a sidewall of a building in a given time. This heat loss or "U" factor is computed on the basis of each degree temperature differential per square foot per hour. It must be noted that the coefficient of transmission is measured from air to air and not from surface to surface.

"K" & "C" FACTORS - In order to obtain the "U" factor for part of a building, it is necessary to know the conductivity coefficient of each individual building material included in the construction. These coefficients are designated commonly as the "K" factors or the coefficients of conductance which is referred to as the "C" factor. The "K" factor refers to the amount of heat that will pass through one square foot of homogeneous material one inch thick, in an hour, for each degree fahrenheit of temperature difference between the two surfaces. The "C" factor refers to any combination of materials that are of such character that is not practical to use "K" coefficient for appraising their heat resisting values. Such materials as hollow tile, building paper, roofing or concrete blocks are examples of materials that are difficult to appriase on the basis of a one-inch thickness. Basically the difference between the "C" factor and the "K" factor is that the "C" factor refers to the actual thickness of the material, however variable, and the "K" factor always refers to a one-inch thickness. Both factors represent rate of heat transfer between two surfaces.

Either "C" or "K" factors or both may be combined with due consideration for whatever air spaces may be present to make up the "U" factor for the total coefficient of transmission of a wall section or for any section of the building.

"R" VALUE - The thermal resistance factor, "R", is the ability of a specific insulation product to resist heat flow. The higher the "R" value, the greater the efficiency of the insulation and the more resistant the material is to heat flow. Thus "R" value implies low heat losses.

"R" is the reciprocal of U, K, or C. R = 1/U; R = 1/K; R = 1/c. "R" factor is the only factor that can be added to find total thermal resistance without figuring the reciprocal.

HEAT LOSS CALCULATIONS

In order to establish how much energy and money can be saved by specific weatherization methods (storm doors/windows, insulation, weatherization, etc.) and to determine the proper size for heating and cooling units, heat loss calculations for the exposed surfaces of the house are required.

The procedure recommended for determining heat loss for the walls, ceiling, and floor of a room or the total house follows. The importance of accurate load calculations cannot be over-emphasized. It is the essential first step to providing comfort in a structure. Accurate design data and logical, step-by-step calculation procedures are included in this unit.

Obtaining Building Dimensions. The dimensions of a new structure are usually obtained from the building plans (blueprints). At least one dimension for each direction should be checked on each sheet of the plans. If a dimension does not correspond to the scaled measurement, determine from the builder or owner which is correct. It is also wise to make sure that all construction changes are shown on the plans.

Blueprints for existing structures should be used only after they have been compared to the structure. In many cases, measurements will have to be obtained from the building.

When measuring for heat transmission, dimensions and areas for closets and halls are usually included with those of adjoining rooms. Large closets or entrance halls should be considered as rooms and their dimensions obtained and recorded separately.

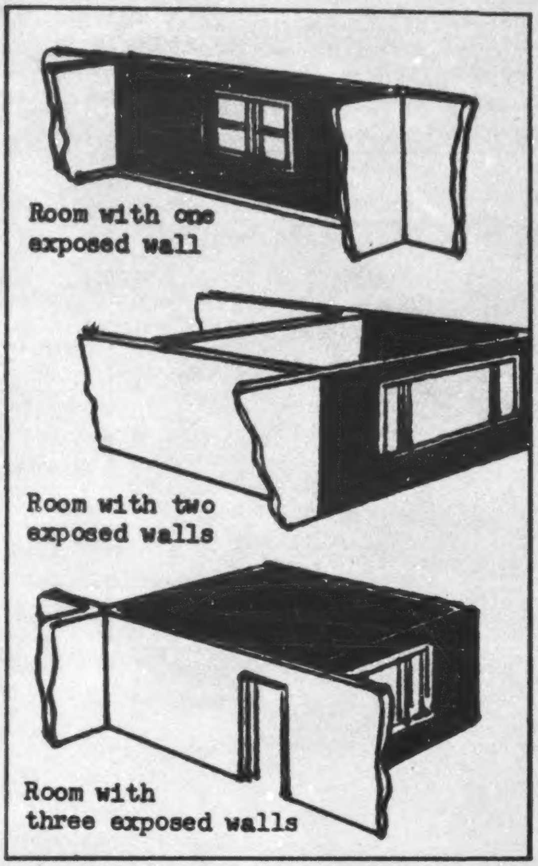

Room with one exposed wall
Room with two exposed walls
Room with three exposed walls

Figure 2e. Floor plans showing running feet of exposed walls for rooms having 1, 2, and 3 wall exposures. (NESCA)

Wall Dimensions

Find the total exposed wall area by multiplying the length by the height. This is the gross wall area. (An exposed wall is one which faces the outside and may be either above or below grade level). Whether length dimensions are obtained by actually measuring or from floor plans, they are recorded to the nearest foot. For example, if the distance is 14 ft. 6 inches, record 15 ft. as the distance. If a room has two or more exposed walls, the total running feet of exposed wall is the sum of the individual wall lengths. (See Figure 2e). Wall height is recorded to the nearest one-half foot. For example, if the measured height is 7 ft. 9 inches, record 8 ft. If more than one type of wall construction is used in a room, record the average height of each construction. Record the average height for walls in a room when the height is not uniform. Gross wall area includes wall, window, and door areas. To obtain the net exposed wall area, subtract the window and door areas from the gross exposed wall area.

Stairways. When an open stairway is located adjacent to a cold outside wall, the exposed wall area up to the ceiling of the second story is included with that of the first story hall or room.

Walls Above and Below Grades. Wall areas above grade are usually recorded separately from wall areas below grade. If a wall extends less than three feet below grade, it is assumed to be entirely above grade; and the area is recorded as if the entire wall were above grade. When a wall extends more than three feet below grade, the above grade wall area and below grade wall are recorded separately. For example:

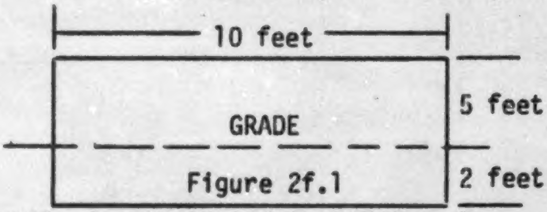


Figure 2f.1

Wall extends less than 3 feet below grade: record entire wall as grade. Total area 2x5x10=70 sq. ft.

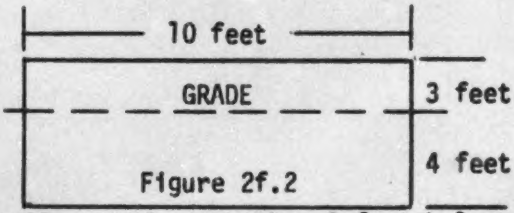


Figure 2f.2

Wall extends more than 3 feet below grade; record as two separate walls. Above area = 3x10=30 sq. ft.

Partitions. A wall that is not directly exposed to outside temperature but separates a conditioned space from an unconditioned space is an exposed partition. Dimensions for exposed partitions are recorded in the same manner as those for exposed walls. (See Figure 2g).

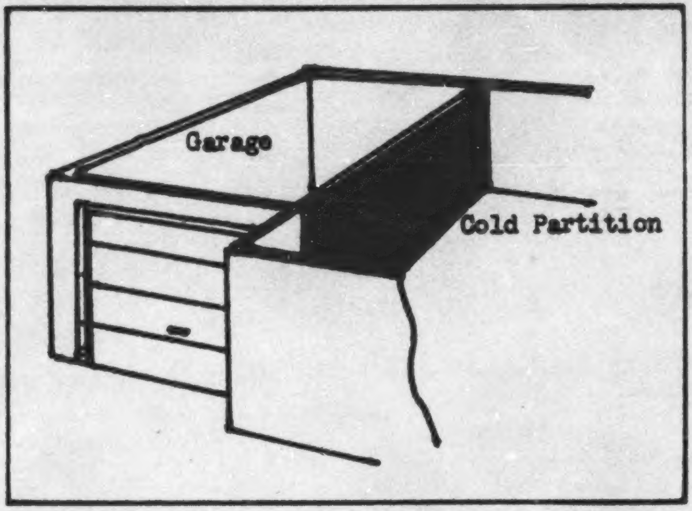


Figure 2g
Cutaway Showing
Cold Partition
Wall (NESCA)

Knee Walls. Knee walls are exposed to the same conditions as ceilings under an unconditioned space. Areas of knee walls should be included with the ceiling area. (See Figure 2h).

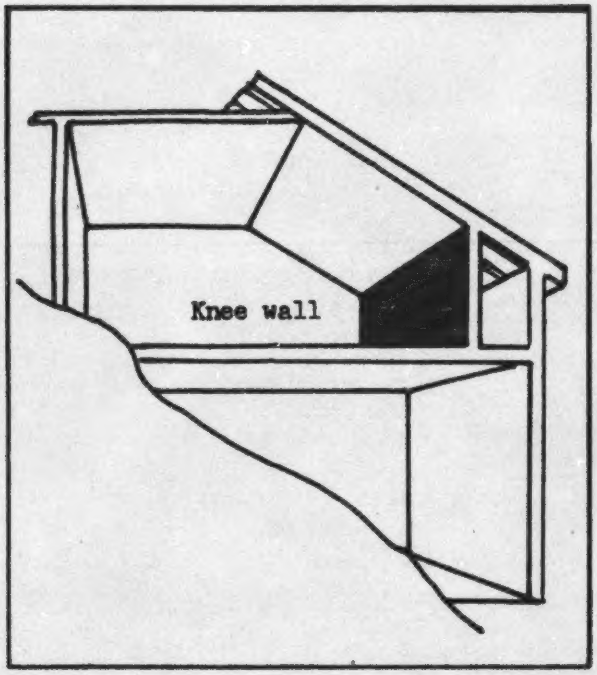


Figure 2h Cutaway Showing Knee Wall (NESCA)

Window & Door Dimensions Measurements of a window and door are illustrated in Figure 2i. Dimensions for windows and doors are measured to the nearest inch and are usually recorded to the nearest 0.1 foot. (Since all dimensions are in square feet).

Dimensions in 0.1 ft. which correspond to dimensions in inches are listed below.

Dimensions Measured, in.	Dimensions Recorded, ft.
1"	0.1
2"	0.2
3"	0.3
4"	0.3
5"	0.4
6"	0.5
7"	0.6
8"	0.7
9"	0.8
10"	0.8
11"	0.9
12"	1.0

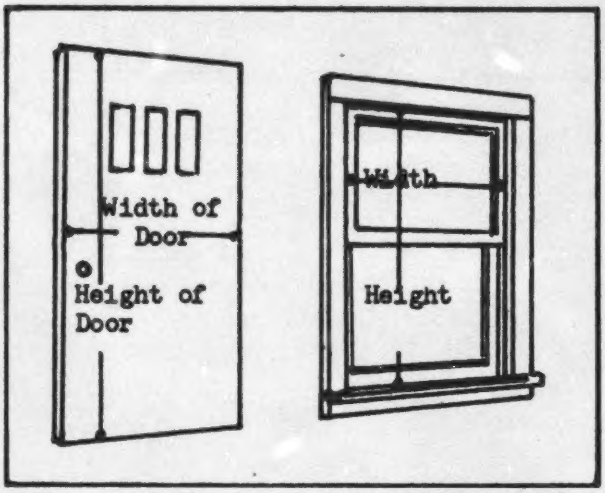

Width of Door
Height of Door
Width
Height

Figure 2i Dimensions Needed for Calculating Window and Door Areas (NESCA)

The area of each window and door is recorded to the nearest square foot, and the total area of each type of window and door for each room is recorded to the nearest square foot.

Step 2) Add the resistance coefficient ("R" values) for each of the materials used in the construction of each wall. (See Table 2.I). Take the reciprocal of the sum. This figure is the "U" factor for the net wall. (Each wall which is constructed differently must be calculated separately). (See Figure 2j). The "U" value can also be determined by using the calculation for "How to Solve for U of Wall" Section IV, Unit III.

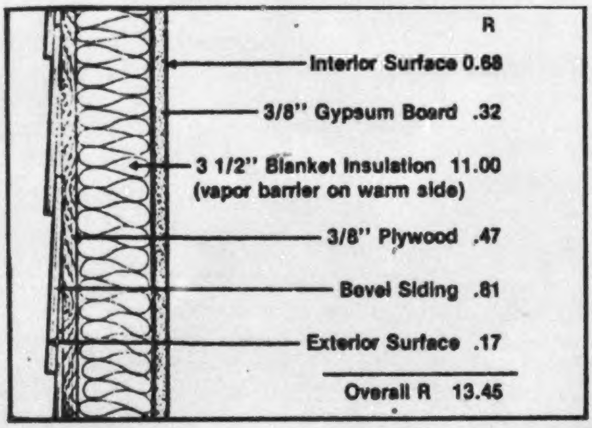

R
Interior Surface 0.68
3/8" Gypsum Board .32
3 1/2" Blanket Insulation 11.00
(vapor barrier on warm side)
3/8" Plywood .47
Bevel Siding .81
Exterior Surface .17
Overall R 13.45

Figure 2j

This list is not intended to include all types of building materials, but only materials commonly used in residences. If necessary, select the material most similar, and the resulting values will not substantially affect the calculation.

MATERIAL	THICKNESS (Inches)	R VALUE	U VALUE
Air Film and Spaces:			
Air space, bounded by ordinary materials	3/4 or more	.91	1.10
Air space, bounded by aluminum foil	3/4 or more	2.17	.46
Exterior surface resistance	--	.17	5.88
Interior surface resistance	--	.68	1.47
Masonry:			
Sand and gravel concrete block	8	1.11	.900
	12	1.28	.781
Lightweight concrete block	8	2.00	.50
	12	2.13	.469
Face brick	4	.44	2.27
Concrete cast in place	8	.64	1.56
Building Materials-General:			
Wood sheathing or subfloor	3/4	1.00	1.00
Fiber board insulating sheathing	3/4	2.10	.476
Plywood	5/8	.79	1.26
	1/2	.63	1.58
	3/8	.47	2.12
Bevel-lapped siding	1/2x8	.81	1.23
	3/4x10	1.05	.952
Vertical tongue and groove board	3/4	1.00	1.00
Drop siding	3/4	.94	1.06
Asbestos board	1/4	.13	7.69
3/8" gypsum lath and 3/8" plaster	3/4	.42	2.38
Gypsum board (sheet rock)	3/8	.32	3.12
Interior plywood panel	1/4	.31	3.22
Building paper	---	.06	16.66
Vapor barrier	---	.00	0
Wood shingles	---	.87	1.14
Asphalt shingles	---	.44	2.27
Linoleum	---	.08	12.5
Carpet with fiber pad	---	2.08	.480
Hardwood floor	---	.71	1.40
Insulation Materials (mineral wool, glass wool, wood wool):			
Blanket or batts	1	3.70	.270
	3 1/2	11.00	.090
	6	19.00	.052
Loose fill	1	3.33	.300
Rigid insulation board (sheathing)	3/4	2.10	.476
Windows and Doors:			
Single window	---	approx-1.00	1.00
Double window	---	approx-2.00	.5
Exterior door	---	approx-2.00	.5

Insulation Value of Common Materials

Step 3) Determine the "U" factor for each door and window in the exterior wall by taking the reciprocal of the resistance coefficient.

Step 4) Calculate the design temperature difference* (ΔT) by subtracting the outside design temperature* from the inside design temperature.* Example:

IDT = 70°, ODT = -10°, therefore 70° - -10°) = ΔT = 80°

---

*Inside Design Temperature. The temperature to be maintained within the structure is the inside design temperature values commonly used as the inside design temperatures are 70°F or 75°F. Seventy degrees is the usual level used for heat loss calculations.

*Outside Design Temperature. The outside design temperature is the average outdoor temperature for either winter or summer. When calculating heat gain the summer design temperature is used. The winter design temperature is used to determine heat loss. Recommended outside design temperatures for many localities are listed in Table 2.II. The outside design temperature is not the lowest or highest temperature recorded in each locality. In Urbana, Illinois, for example, the lowest temperature recorded over a period of about 50 years was 21 degrees below zero (-21°F). The temperature remained at this low point for less than two hours.

*Design Temperature Difference. (Δt) The difference between the outside design temperature and the inside design temperature is the design temperature difference.

CITY	WINTER DRY BULB TEMP (F)	SUMMER DRY BULB TEMP (F)	LATITUDE
BECKLEY	5	90	40°N
BLUEFIELD	10	85	35°N
CHARLESTON	10	90	40°N
CLARKSBURG	5	90	40°N
ELKINS	5	85	40°N
HUNTINGTON	10	95	40°N
MARTINSBURG	10	95	40°N
MORGANTOWN	5	90	40°N
PARKERSBURG	10	90	40°N
WHEELING	5	90	40°N

Table 2.II. Outside Design Temperatures - West Virginia

Step 5) Determine the BTU loss per hour (BTU/H) for the net wall area by multiplying the net wall area by the net wall "U" factor by the design temperature difference. Record this figure.

BTU/H net wall area = Net wall area x U factor x temperature difference

Step 6) Determine the BTU/H for the windows by multiplying the window area by the glass "U" factor by the design temperature difference. Record this figure.

BTU/H net window area = window area x U factor x temperature difference

Ceiling Dimensions

Step 1) Find the total exposed ceiling area by multiplying the length by the width. A room has an exposed ceiling when it is located directly beneath an attic, roof or other unconditioned space. Thus, all rooms in a one-story house have exposed ceilings. In a two-story house, all rooms on the second story have exposed ceilings. Some rooms on the first story of a two-story house may have exposed ceilings. An example of this is a room located under an attic space which behind a knee wall. (See Figure 2k).

Determine the area of exposed ceiling for each room by multiplying the room width by its length. Width and length of the room are measured to the nearest foot. NOTE: When only part of the ceiling of a room is exposed, determine the area for the exposed portion only.

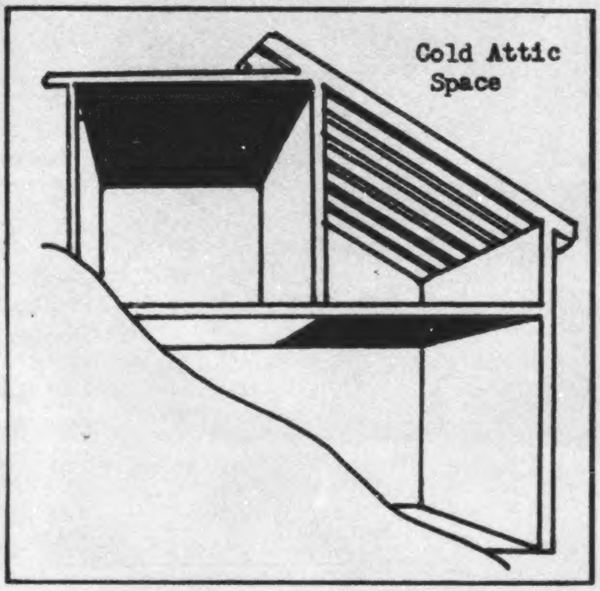

Cold Attic Space

Figure 2k Cutaway Showing Cold Ceiling Areas (NESCA)

Step 2) Determine the "U" factor for the ceiling by adding the "R" values for each material used and take the reciprocal. (See Figures 2l and 2m).

Example: U factor ceiling = 1.00 ÷ Total resistivity

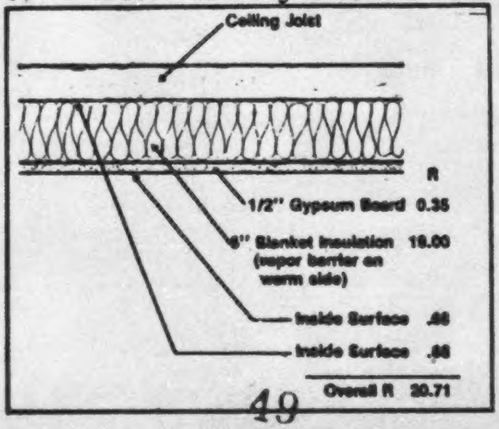

Ceiling Joist
R
1/2" Gypsum Board 0.35
6" Blanket Insulation 19.00
(vapor barrier on warm side)
Inside Surface .68
Inside Surface .68
Overall R 20.71

Figure 2l

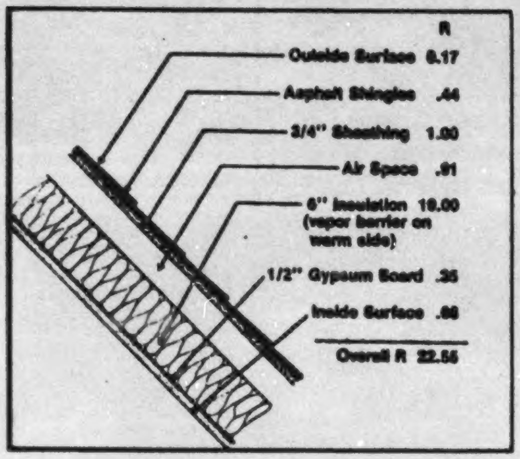


Figure 2m

Step 3) Calculate the BTU/H by multiplying the ceiling area, by the total ceiling U factor, by the design temperature difference. Example:

BTU/H for ceiling = Ceiling area x U factor x temperature difference

Floor Dimensions

Step 1) Find the total floor area (figure heat loss only for floors over non-heated areas such as crawl space or slab type floors) of the floor by multiplying the length by the width.

When taking measurements for the purpose of determining heat loss through floors, all floors that are located over unconditioned spaces, exposed to outside temperature or in contact with the ground must be considered. For determining heat gain from floors, only floors located over unconditioned spaces or those exposed to outside temperatures are considered. (Unconditioned spaces are rooms, basements, or enclosed and unvented crawl spaces that do not have conditioned air supplied to them). If only part of a floor is exposed, then only that portion is considered. An example of this is a room, part of which is located over an open porch. (See Figure 2n). Since the rate of heat flow is uniform through floors located over unconditioned rooms, open or vented spaces, and basement floors, the heat transmission through those is based on their area. Measure the width and length of these floors to the nearest foot and record the area to the nearest square foot.

Most of the heat loss from concrete slab floors is near the edge of the floor. Heat loss for these floors is, therefore, based on the length of floor exposed to outside temperature. This is measured and recorded to the nearest foot.

Basement and concrete slab floors are not considered when obtaining measurements for the purpose of determining heat gain.

Step 2) Determine the U factor for the floor by adding the resistance for each material used and take the reciprocal. Example:

1.00 ÷ total "R" value =
"U" factor of floor

(See Figure 2o).

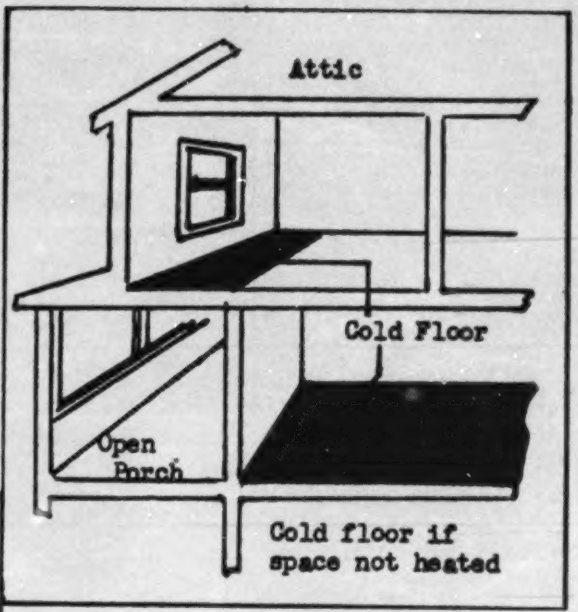

Attic
Cold Floor
Open Porch
Cold floor if space not heated

Figure 2n Cutaway Showing Cold Floor Areas (NESCA)

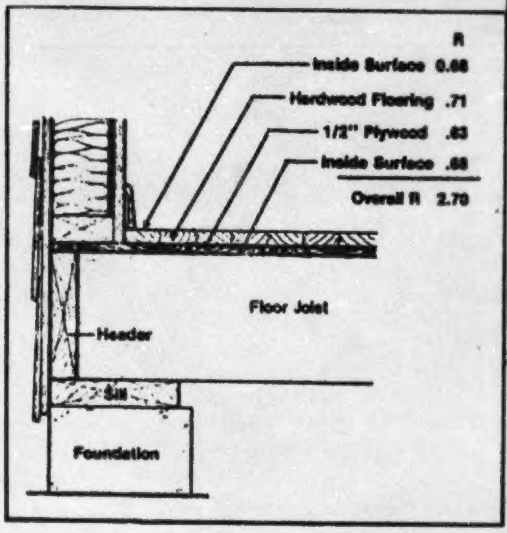

R
Inside Surface 0.68
Hardwood Flooring .71
1/2" Plywood .63
Inside Surface .68
Overall R 2.70
Floor Joist
Header
Sill
Foundation

Figure 2o

Step 3) Calculate the BTU/H by multiplying the floor area, by the total floor U factor, by the design temperature difference. Example:

BTU/H for the floor = floor area x U factor x temperature difference

Note that the design temperature difference may not be the same here as for the walls and ceilings because of uninsulated heating duct and hot water pipes. If the area is properly vented pipes and ducts are insulated, then the same design temperature difference may be used.

Infiltration

Heat loss through spaces around windows and doors is known as infiltration. For calculation purposes, it has been estimated that infiltration is equal to one air exchange per hour. For example, if a room is 10' x 18' and has an 8 foot ceiling, the total volume is 1440 cubic feet. This figure, 1440 cubic feet, is the amount of air infiltration.

NOTE: If heat loss load calculations are determined by utilizing Manual J of the National Environmental Systems Contractors Association, the infiltration is figured into the heat loss multipliers provided in the manual.

Step 1) Determine the volume of air in the room or home under consideration by multiplying the length by the width by the height. This volume is equal to the air infiltration.

Step 2) Calculate the air infiltration BTU/H heat loss by multiplying the volume of air infiltration by the U factor (.018) by the design temperature difference. Note that .018 BTU/H is required to warm 1 cubic foot of air 1 degree fahrenheit. (One BTU/H is required to warm 55 ft. of air 1°F). This is a constant and may be used in each calculation.

Final Calculations

Step 1) List the BTU/H for the walls, windows, doors, ceiling, floor, and air infiltration.

Step 2) Add the results of each together to find the total heat loss in BTU/s per hour. This figure represents the size of the heating units required for the room or home. These calculations can also be used to compare how various building materials effect the heat loss of home. An example of this is determining the heat loss of the room without storm windows and insulation versus a heat loss of the room with insulation and storm windows. (This example and others will follow).

The procedure for calculating the size of a cooling unit is about the same except that the design temperature difference must reflect summer temperatures rather than winter and allowance should be made for very humid locations. The design temperature for cooling is found on page 9 of this unit.

EXAMPLE

The purpose of the following example is to apply the procedures just described to a room to show actual computation of heat loss. Figure 2p shows the room used in the example.

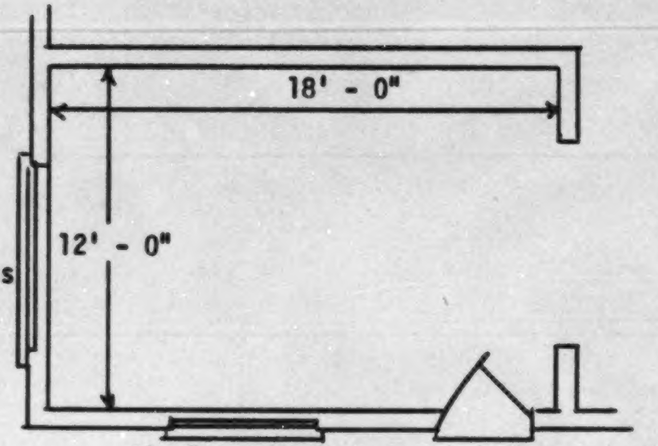

18' - 0"
12' - 0"
6'-0" by 5'-0"
Window with
Insulating Glass
6'-0" by 5'-0"
Window with
Insulating Glass
3'-0" by 6'-8"
Door, 1 3/4"
Thick

Figure 2p

Wall Calculations

(1) TOTAL EXTERIOR AREA 12' - 0" x 8' - 0" = 96 sq. ft.
18' - 0" x 8' - 0" = 144 sq. ft.

Gross wall area = 240 sq. ft.

(2) WINDOW AREA 6' - 0" x 5' - 0" = 30 sq. ft.
6' - 0" x 5' - 0" = 30 sq. ft.

Total window area = 60 sq. ft.

DOOR AREA = 3' - 0" x 6' - 8" = 21 sq. ft.
Total door area = 21 sq. ft.

NET WALL AREA = Gross wall area - door and window area

= 240 sq. ft. - 60 sq. ft. + 21 sq. ft.

= 240 sq. ft. - 81 sq. ft.

NET WALL AREA = 159 sq. ft.

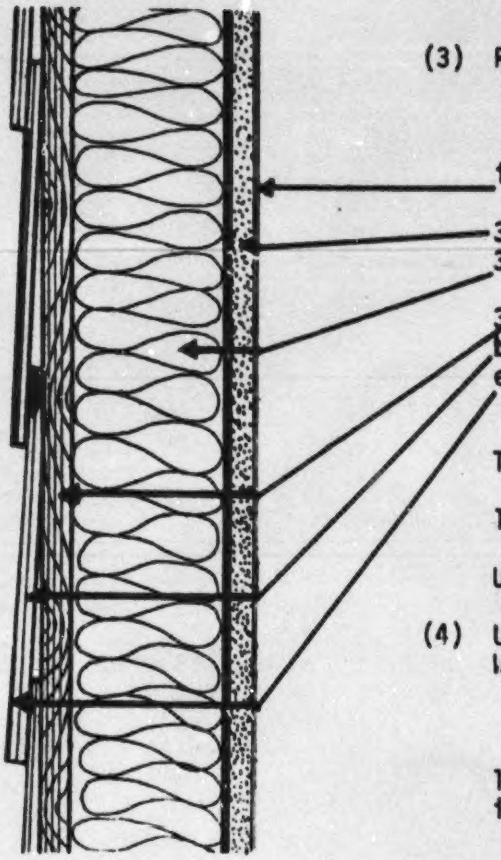


Figure 2

(3) RESISTANCE OF WALL MATERIALS

	"R"
interior surface (dead air space)	.68
3/8" gypsum board	.32
3-1/2" blanket insulation	11.00
3/8" plywood	.47
bevel siding	.81
exterior surface (dead air space)	.17
TOTAL RESISTIVITY	13.45

1.00 ÷ 13.45 = .074

U FACTOR FOR NET WALL = .074

(4) U FACTOR FOR DOORS AND WINDOWS

	"R"
1-3/4' wood door (.52)	1.92
insulating glass window (.53 for both windows)	1.88

(5) DESIGN TEMPERATURE DIFFERENCE

Inside design temperature	70°	
Outside design temperature	5°	(Morgantown, West Virginia)
Design temperature difference =	65°	

(6) BTU/H FOR NET WALL

Net wall area x U factor x temperature difference

159 sq. ft. x .074 x 65

BTU/H for the net walls = 765 BTU/HR

(7) BTU/H FOR THE WINDOWS

Window area x U factor x temperature difference

60 sq. ft. x .53 x 65

BTU/H for the windows = 2067 BTU/HR

(8) BTU/H FOR THE DOOR

Door area x U factor x temperature difference

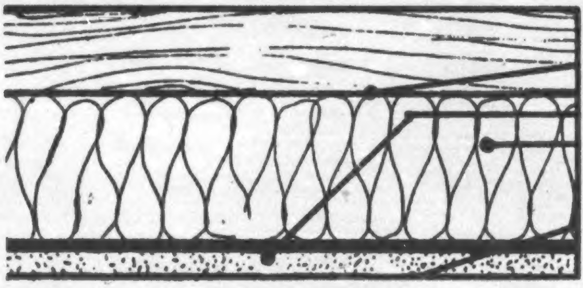
21 sq. ft. x .52 x 65

BTU/H for the door = 709.8 = 710 BTU/HR

Ceiling Calculations

(1) TOTAL CEILING AREA - 12' - 0" x 18' - 0" = 216 sq. ft.

(2) U FACTOR FOR CEILING



inside surface (dead air space)	.68
1/2" gypsum	.35
6" blanket insulation	19.00
outside surface (dead air space)	.68
Total resistivity	20.71

Figure 2r

1.00 ÷ 20.71 = .048

U factor for ceiling .048

(3) BTU/H FOR THE CEILING

ceiling area by U factor x temperature difference

216 sq. ft. x .048 x 65

BTU/H for the ceiling - 673.92 = 674

Floor Calculations

(1) TOTAL FLOOR AREA - 12' - 0" x 18'0" = 216 sq. ft.

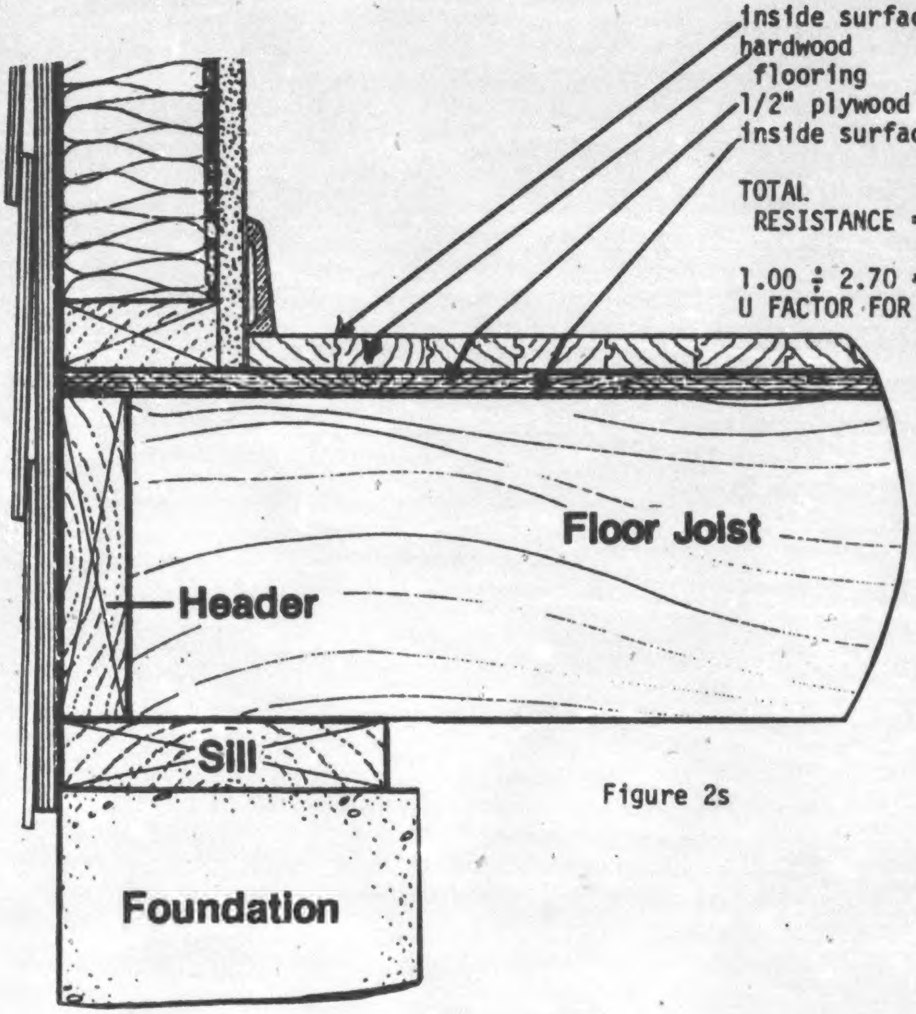
(2) U FACTOR FOR FLOOR - 1.00 ÷ 2.70 = .370

(3) BTU/H FOR THE FLOOR

floor area x U factor x temperature difference

216 sq. ft. x .370 x 65°

BTU/H FOR THE FLOOR = 5195 BTU/HR


Floor Joist
Header
Sill
Foundation

inside surface	.68
hardwood flooring	.71
1/2" plywood	.63
inside surface	.68

TOTAL RESISTANCE = 2.70

1.00 ÷ 2.70 = .370
U FACTOR FOR FLOOR = .370

Figure 2s

Air Infiltration Calculations

(1) VOLUME OF AIR

length x width x height

18' - 0" x 12' x 8' - 0" = 1728 cu. ft.

volume of air = air infiltration

(2) BTU/H FOR AIR INFILTRATION

volume of air x .018 x temperature difference

1728 cu. ft. x .018 x 65

BTU/H for air infiltration = 2021.76 = 2022 BTU/HR

Summary

BTU/H for net walls	765
BTU/H for net windows	2067
BTU/H for the door	710
BTU/H for the ceiling	674
BTU/H for the floor	5195
BTU/H for air infiltration =	2022
Total BTU/H =	11433

The total room heat loss is 11,433 BTU/H. A heating unit capable of producing this amount of heat is required for the room used in this example. By conservation methods such as insulation, caulking, weatherstripping, and/or adding storm windows as outlined in Unit 3 this heat loss would be greatly reduced.

PREDICTING FUTURE NEEDS*

Once the heat loss for a room or home has been determined, the fuel costs for heating season can be estimated. Determining the heating costs of various systems will give an idea of which fuel and system will provide the home with the greatest comfort for the money spent. Note also that heating costs can vary according to how well the house has been weatherized.

If the heat loss calculations for a building were accurate for the design conditions, and if the heat loss at any other outside temperature were proportional to that at design conditions, then the heat loss from the building for a whole heating season could be expressed by the equation:

---

*Source: Storck & Koral: Handbook of Air Conditioning, Heating and Ventilating - 2nd Edition, Published 1959, 1965 by Industrial Press, Inc. Reprinted with permission.

$$H = \frac{24hd(t_i-t_a)}{t_i-t_o}$$

where H = seasonal heat loss in BTU,

h = hourly heat loss from the building for the design conditions, BTU,

t_i = inside design temperature, deg F,

* t_o = outside design temperature, deg F,

24 = hours per day,

* d = number of days in the heating season,

t_a = average outside temperature for the heating season.

* (See Appendix A & B in back of this unit for Figures.)

For buildings where the inside design temperature is 70 deg, the formula becomes:

$$H = \frac{24hd(70-t_a)}{70-t_o}$$

EXAMPLE

What would be the heat required for a residence in New York where the design heat loss is 70,000 BTU per hour, $d=241$, $t_a=44.0$ degrees, $t_o=0$ degrees and the $t_i=70$ degrees?

Substituting in the equation above:

$$H = \frac{24 \times 70{,}000 \times 241 \times (70-44)}{(70-0)}$$

H = 150,384,000 BTU the heat loss for the whole heating season

Determining Fuel Use

The heat loss for the whole heating season can be converted into fuel units by dividing by the heat value per fuel unit and by the utilization efficiency. For example, assuming 1031 BTU per cubic foot of natural gas at 75% efficiency, the gas consumption per season would be:

$$\text{fuel use} = \frac{150,384,000}{1031 \times .75}$$

$$= \frac{150,384,000}{773.25}$$

$$= 194,483 \text{ cu. ft.}$$

HEAT VALUE/COST/EFFICIENCY PER FUEL

Fuel	Heat Value (BTU)	Approximate Cost*	Efficiency (%)
Natural Gas	1031/cubic foot	$3.00/mcf	75
#1 Heating Oil	136,000/gallon	.592/gallon	75
#2 Heating Oil	140,000/gallon	.66/gallon	75
Bottle Gas Propane	93,000/gallon	.558/gallon	75
High Volalite Bituminous Coal	26,000,000/ton	45.00/ton	65
Electric Resistance Heat	3412/kilowatt	.05/kwh	100

*Estimated Average Cost July, 1979 Morgantown, West Virginia

Determining Fuel Cost

The cost of the fuel for the entire heating season can be determined by multiplying the fuel use unit by the fuel cost. For example, assuming 194,483 cubic feet of natural gas at $3.00 per thousand cubic feet of gas, the gas cost per season would be

= 194.483 x $3.00

= $583.449 per heating season

EXAMPLES FOR VARIOUS FUEL

$$\text{Heat Loss} = \frac{24 \times 32,787 \times 238\ (70 - 40)}{70 - 5}$$

$$= \frac{187,279,344 \times 30}{65}$$

$$= \frac{5.618380320}{65}$$

= 86,436,620 BTU's required for one heating season

NATURAL GAS $\frac{86{,}436{,}620}{.75 \times 1031 \text{ BTU/Cu. Ft.}}$ = 111783.53 Cubic Feet of Gas

$$\text{MCF} = \frac{111783.53}{1000}$$

= 111.78 MCF

cost = MCF x $3.00
= 111.78 x $3.00
= $335.35 per heating season

#1 HEATING OIL $\frac{86{,}436{,}620}{.75 \times 136{,}000 \text{ BTU/Gal.}}$ = 847.41 Gallons of oil

cost = gallon x .592
= 847.42 x .592
= $501.67 per heating season

#2 HEATING OIL $\frac{86{,}436{,}620}{.75 \times 140{,}000 \text{ BTU/Gal.}}$ = 823.20 Gallons of oil

cost = gallon x .66
= 823.20 x .66
= $543.31 per heating season

BOTTLE GAS PROPANE $\frac{86{,}436{,}620}{.75 \times 93{,}000 \text{ BTU/Gal.}}$ = 1213.14 Gallons of Propane

cost = gallon x .558
= 1213.14 x .558
= $676.93 per heating season

COAL $\frac{86{,}436{,}620}{.65 \times 26{,}000{,}000 \text{ BTU/Ton}}$ = 5.11 Tons of Coal

cost = Tons x $45.00
= 5.11 x 45.00
= $230.15 per heating season

ELECTRIC $\frac{86{,}436{,}620}{1.00 \times 3412/\text{KW}}$ = 25,333 KW

cost = KW x .05 = 25,333 x .05 = $1266.65 per heating season

APPENDIX A

Air Conditioning Design Data*

(Delaware, District of Columbia, Maryland,
Pennsylvania, Virginia, West Virginia)

State & Station	Winter Dry Bulb Temp.(f)	Summer Dry Bulb Temp.(f)
DELAWARE:		
Bethany Beach	20	87
Dover AFB	15	90
Lewes	19	87
Miles, Fort	19	87
Wilmington	11	90
DISTRICT OF COLUMBIA:		
Andrews AFB, Walter Reed Hosp	16	91
National Arpt	17	93
MARYLAND:		
Annapolis USNA	16	86
Baltimore Aprt	15	91
Bethesda Naval Medical Ctr.	17	92
Chesapeake Beach NRL	19	88
Cumberland	11	90
Frederick	9	91
Hagerstown	6	90
Ocean City	20	87
PENNSYLVANIA:		
Allentown	12	89
Altoona	0	87
Beaver Falls	8	89
Bethlehem	12	89
Brookville	0	87
Clarion	-1	90
Clearfield	0	91
Columbia	5	91
Connellsville	3	87
DuBois	0	87
Erie	6	85
Geneva	2	90
Harrisburg	14	92
Hazleton	8	85
Johnstown	6	87
Lancaster	5	91
Latrobe	8	89
Mechanicsburg	14	92
New Castle	4	90
Oil City	0	90
Phillipsburg	-2	85
Pittsburgh	9	87
Reading	14	90
St. Marys	-3	88
Uniontown	8	89
Waynesburg	6	89
Williamsport	7	89
York	14	92
VIRGINIA:		
Bedford	15	92
Belvoir, Fort	17	91
Blackstone	19	92
Bowling Green	18	94
Cape Henry	24	92
Charlottesville	15	90
Covington	18	91
Dulles Int Arpt	13	91
VIRGINIA (Continued)		
Fisherville	15	90
Hampton	22	92
Lynchburg	18	89
Marion	14	88
Myer, Fort	17	93
Newport News	22	92
Norfolk	25	91
Northwest	25	92
Petersburg	18	94
Richmond	18	94
Roanoke	18	91
Staunton	15	90
Virginia Beach	24	92
Williamsburg	19	91
Yorktown	22	92
WEST VIRGINIA:		
Beckley	6	88
Bluefield	11	88
Charleston	14	90
Clarksburg	7	91
Elkins	5	84
Fairmont	7	91
Huntington	18	93
Martinsburg	7	93
Morgantown	11	88
Parkersburg	11	90
Ripley	10	93
Wheeling	9	87

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*Source: Storck & Koral: Handbook of Air Conditioning, Heating and Ventilating - 2nd Edition, Published 1959, 1965 by Industrial Press, Inc. Reprinted with permission.

APPENDIX B

Data on Normal Heating Season*

(Delaware, District of Columbia, Maryland,
Pennsylvania, Virginia, West Virginia)

State & Station	Average Date Season Begins	Average Date Season Ends	Day Per Season	Average Temp. Degree F.	No. of Degree Days
DELAWARE:					
Dover+	Sept 25	May 20	238	45.7	4591
Milford+	Sept 28	May 17	232	46.5	4303
Wilmington-A	Sept 27	May 19	235	44.1	4910
DISTRICT OF COLUMBIA:					
Washington-A	Oct 2	May 14	225	45.7	4333
Washington-C	Oct 2	May 12	223	45.9	4258
Silver Hill Obs.	Sept 28	May 17	232	45.4	4539
MARYLAND:					
Annapolis+	Sept 24	May 17	236	46.0	4483
Baltimore-A	Sept 28	May 19	234	45.3	4611
Baltimore-C	Sept 8	May 13	248	48.1	4203
Cambridge+	Oct 1	May 13	225	46.1	4245
Frederick-A	Sept 29	May 16	230	43.9	4854
PENNSYLVANIA:					
Allenton-A	Sept 18	May 26	251	41.6	5880
Altoona+	Sept 8	Jun 7	273	42.6	6121
Coatesville+	Sept 19	May 26	250	43.7	5365
Erie-C	Sept 20	Jun 4	258	41.3	6116
Franklin+	Sept 5	Jun 11	280	42.2	6383
Harrisburg-A	Sept 22	May 20	241	43.2	5258
Lancaster+	Sept 13	May 27	257	43.7	5482
Lebanon+	Sept 16	May 28	255	43.1	5585
New Castle+	Sept 12	May 30	261	42.2	5958
Philadelphia-A	Sept 28	May 19	234	44.2	4866
Philadelphia-C	Oct 2	May 17	228	45.2	4523
Pittsburgh-Gr. Pitt.-A	Sept 19	May 29	253	41.7	5905
Pittsburgh-C	Sept 28	May 19	234	43.4	5048
Reading-C	Sept 26	May 21	238	43.7	5060
Scranton-C	Sept 15	May 30	258	41.6	6047
Uniontown+	Sept 10	May 24	257	44.9	5176
Warren+	Sept 2	Jun 18	290	41.8	6740
Williamsport-A	Sept 18	May 28	253	41.7	5898
York+	Sept 16	May 26	253	43.5	5449
VIRGINIA:					
Cape Henry-C	Oct 12	May 12	213	49.5	3307
Charlottesville+	Sept 17	May 12	238	47.3	4223
Danville+	Oct 8	May 6	211	48.4	3511
Lynchburg-A	Sept 29	May 12	226	46.6	4153
Norfolk-A	Oct 8	May 11	216	49.0	3454
Norfolk-C	Oct 13	May 7	207	49.9	3119
Richmond-A	Oct 4	May 12	221	47.1	3955
Richmond-C	Oct 6	May 9	216	47.8	3720
Roanoke-A	Oct 1	May 14	226	46.6	4152
Wytheville+	Sept 13	Jun 2	263	45.9	5022
WEST VIRGINIA:					
Charleston-A	Oct 1	May 17	229	45.7	4417
Elkins-A	Sept 12	Jun 6	268	43.5	5773
Fairmont+	Sept 20	May 23	246	44.5	5047
Huntington-C	Oct 4	May 11	220	46.5	5047
Parkersburg-C	Sept 30	May 18	231	44.4	4750
Petersburg-C	Sept 23	May 22	242	44.5	4966
Wheeling+	Sept 19	May 21	276	46.1	5218

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*Source: Storck & Koral: Handbook of Air Conditioning, Heating and Ventilating - 2nd Edition, Published 1959, 1965 by Industrial Press, Inc. Reprinted with permission.

unit 3

WEATHERIZATION

This unit explains the facts about weatherization of the house and the options relating to it. The unit provides techniques for inspection, selection, application; and evaluation of weatherizing. Weatherization is an energy conservation treatment applied to buildings to reduce air infiltration and heat transfer. It also provides a savings to the consumer by a reduction in energy, provides comfort by maintaining the humidity level, and a reduction of noise and airborne contaminants.

Weatherization can be divided into a variety of options. These options include caulking, weatherstripping, adding storm windows and doors, and insulating the house. The order in which the options appear in the text are in the order of priority, first to last. These priorities depend on the amount of labor involved to install them, the investment of the materials, and the effectiveness of the application.

Home Energy Conservation Primer

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Weatherization

Weatherization is a relatively simple energy conservation improvement to reduce air leaks, drafts, and heat loss through walls, ceilings, windows, and doors. This corrective action can save a great deal of the hommowners' energy dollars and at the same time conserve our decreasing fuel supply. Homes in 1973 directly used 22% of our total energy budget and 36% of our electric energy. Over 60% of this consumption went for space heating and cooling.

Regardless of the type of heating or cooling system used in the home, the proper weatherization techniques, i.e., caulking, weatherstripping, storm windows and doors, and bulk insulating materials are necessary to avoid excessive heat loss in winter and gain in summer. Most homes built before 1965 have about 1-1/2" of insulating material in the ceiling, none in the walls and floors, and plain single strength windows. (See Figures 3.1 & 3.2, Position of Total Heat Loss Attributable to Particular Parts of the House.)

OPTIONS

There are four practical and relatively simple weatherizing options that can be "retrofitted" into an existing home: caulking, weatherstripping, storm windows and doors, and insulation.

The use of weatherstripping, door gaskets, caulking, and similar materials minimizes infiltration, significantly reducing heat loss in the winter. Weatherstripping and caulking are also easy for the homeowner to add himself. In some homes about one-third of the heating energy is used to warm the air which leaks into the home.

Storm doors and windows can cut up to half of the heat loss through exposed surfaces. In many cases the cost of new windows and doors may be prohibitive to the low income consumer, so a thrift alternative is to seal doors (that are not in use) and windows with plastic sheeting available at most hardware and department stores.

Probably the most dollar and energy saving measure a homeowner can take is installing insulation. It can reduce heat waste as much as 30%. The most common type used is fibrous insulation--mineral wool, glass, or cellulose--which is relatively easy to install in ceilings and attics. Wall insulation is a different matter; it should be installed by professional help. Ideally, every wall and ceiling exposed to the outside air should be properly insulated.

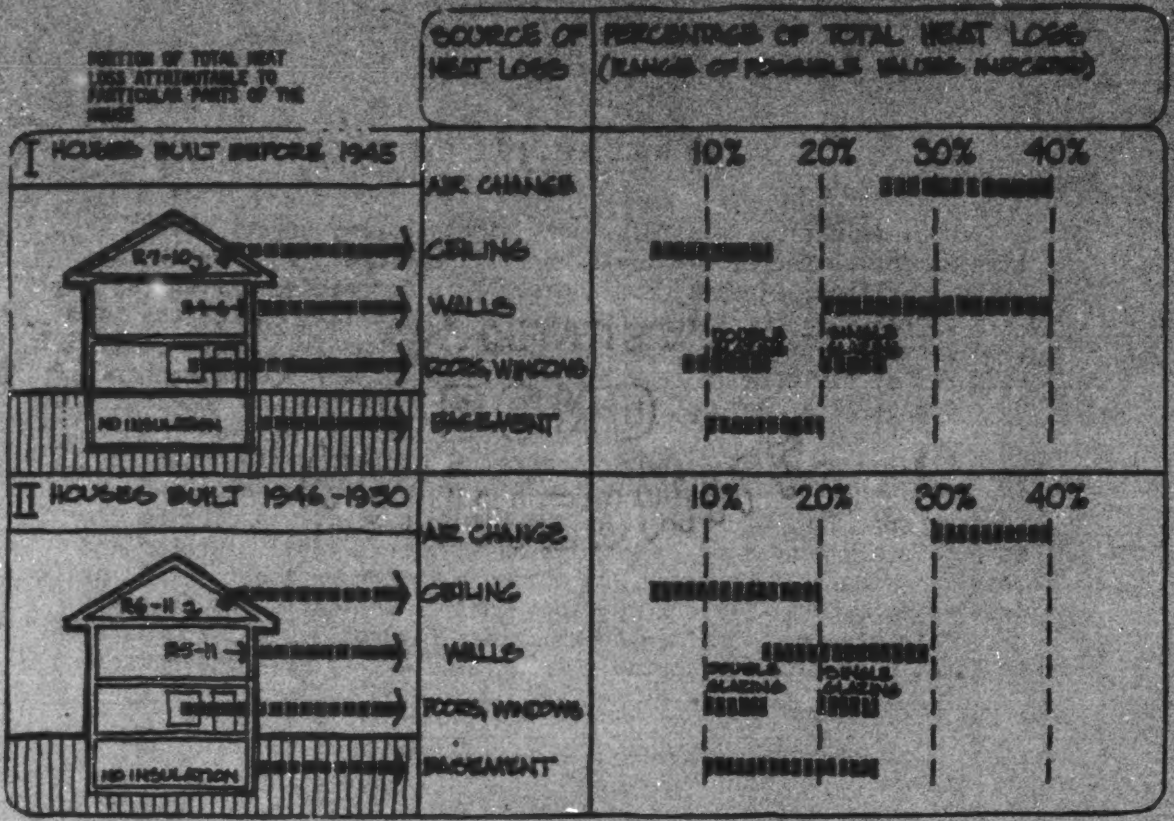


Figure 3.1 Reprinted from KEEPING THE HEAT IN, Energy, Mines and Resources Canada

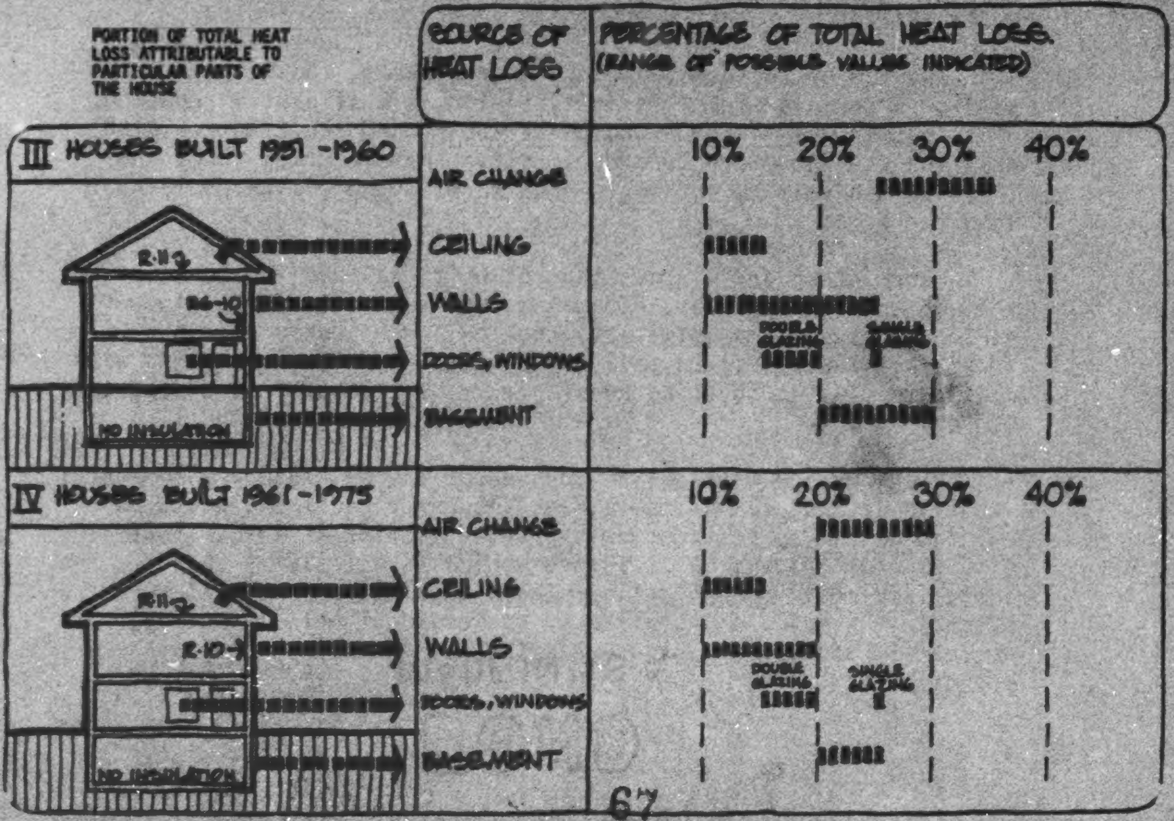


Figure 3.2 Reprinted from KEEPING THE HEAT IN, Energy, Mines and Resources Canada

DETERMINING PRIORITIES

Weatherizing techniques are usually divided into components. These components already listed as weatherstripping, caulking, storm doors and windows, and insulating provide the homeowner with savings and comfort provided they are selected economically and applied properly. The costs of carrying out these home improvements can vary enormously. For example--inexpensive plastic film over windows can serve as storm windows at minimal costs. Full insulation of an existing structure can be accomplished by blowing in insulation; the effectiveness and expense are difficult to estimate. For homes with accessible attics, laying thermal insulation can be accomplished by the average home handyman for only the costs of the materials. Caulking and weatherstripping are very easy to install and payback is economically justified when the work is done by the do-it-yourself type of person. On the other hand it becomes very uneconomical to have a contractor apply such materials. All weatherstripping techniques therefore must be individually selected for the proper application and installed properly for maximum efficiency.

To determine the priority in which to apply various weatherizing options depends on a number of things such as effort, cost, and effectiveness. All buildings are different and have a variety of problems. All homes don't require the same applications, but what ever retrofitting option is selected, certain criteria should be used to determine the priority. These are:

1. DETERMINE THE PRIMARY SOURCE OF THE PROBLEM. Before selecting a material the primary source of the problem must be found. For example, if heat loss is taking place in the home--where is the location of the leakage: doors, windows, ceiling, walls, floor, chimney.

2. DETERMINE EXPENSE OF OPTION. Before doing any retrofitting the expense should be taken into consideration. Many retrofitting options are not economical and the payback period of the option far exceeds the material. For example, installing triple glaze storm windows rather than using plastic storm windows which are less expensive and just as effective if applied correctly.

3. DETERMINE THE AMOUNT OF LABOR INVOLVED. Labor costs can make weatherizing very uneconomical. In many cases labor is more expensive than the fuel bills and material costs and the payback period never catches up to fuel costs. Many weatherizing options can be done by the handyman which saves money and shortens the payback period. Installing insulation in an attic for example can usually be done by a handyman to reduce costs although a contractor should be used as a consultant for many jobs and should do professional types of installation such as blowing or foaming loose-fill and foam insulations.

4. DETERMINE THE EFFECTIVENESS OF THE OPTION. Is the material going to perform for the designated task and is the material selected going to eliminate the problem? The mistake is often made that the option chosen for the problem is not an effective choice. For example, a house that has a high heat loss due to infiltration will not be corrected by installing insulation. Infiltration will be reduced, but the greatest amount will still exist along with the heat loss. Another example of this is adding additional materials to those previously installed, such as insulation in an attic. After a certain amount, the effectiveness of the insulation decreases and the payback period is extended. See Graphs 3I & 3II.

5. PAYBACK PERIOD. Many weatherizing options are applied with little concern for the amount of time the option will take to pay for itself. Payback depends on the initial expense of the option (material and labor) and the energy costs over a given time. Inexpensive options such as caulking, weatherstripping, and adding plastic storm windows may have a payback of a few months, while installing storm doors and insulation may have an extended payback period of many years.

To provide the consumer the most effective and efficient option it is necessary that the selection be made by using the above criteria. The rest of this unit will provide an indepth look at specific weatherization options, listed according to priority.

SECTION II

Caulking and Weatherstripping

Air leakage (infiltration or exfiltration) can be a major factor in energy waste created by the home's heating and cooling system. Even if a house is well insulated, a reduction of heating and cooling can take place by caulking and weatherstripping the home. Insulation slows down heat loss through walls, roofs, and floors but it won't stop cold air from leaking in through cracks around doors, windows, air conditioners, and exterior trim. The job of stopping cold air infiltration falls to weatherstripping and caulking. Both caulking and weatherstripping are easy, economical do-it-yourself jobs. Even if the home has no caulking or weatherstripping $35.00 to $80.00 should take care of the materials (depends on the size of the house). A savings payback on heating and cooling usually occurs from three to 12 months. There are other reasons to caulk and weatherstrip. A list of these follows:

Why ??

-Stops heat loss and infiltration through:

doors
windows
cracks
vents
dampers
chimney
fireplaces
walls
outlets
light fixtures
floors

-Saves 15% to 30% on heating and cooling costs.

-Reduces winter heat loss and summer heat gain.

-Eliminates uncomfortable drafts.

-Helps maintain comfortable humidity factor (30-40%).

-Keeps soot, dust, and other airborne contaminates out.

-Cushions noise from closing doors and windows.

-Stops doors and windows from rattling in a sharp wind.

-Prevents entrance of vermin.

-Caulking will prevent seepage of moisture into home where it can cause rot and paint peeling.

-Prevent seepage of moisture where it can soak insulation, rendering it ineffective.

Where To Caulk

Caulking should be applied wherever two different materials or parts of the house meet.

-Between window drip caps (tops of windows) and siding.

-Between door drip caps and siding.

-At joints between door frames and siding.

-At joints between window frames and siding.

-Between window sills and siding.

-At corners formed by siding.

-At sills where wood structure meets the foundation.

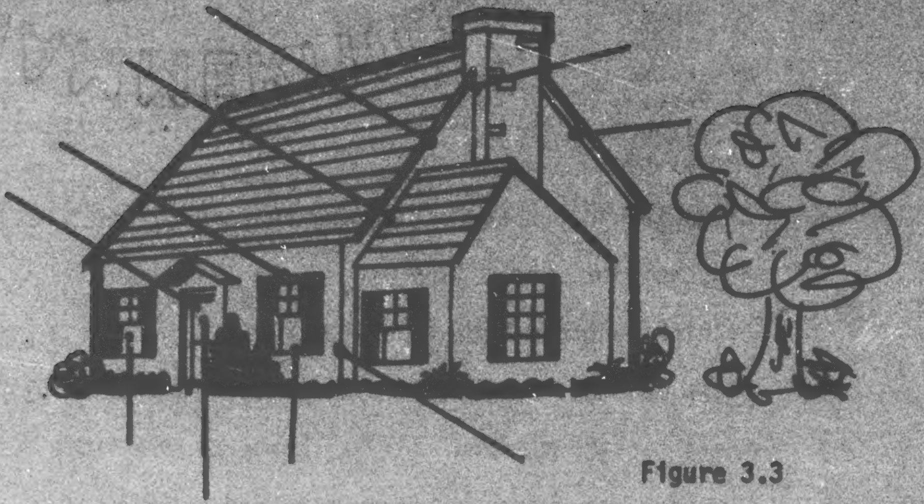


Figure 3.3

- -Outside water faucets, or other special breaks in the outside house surface.

- -Where pipes and wires penetrate the ceiling below an unheated attic.

- -Between porches and main body of the house.

- -Where storm windows meet the window frame, except for drain holes at window sill.

- -And if you have a heated attic; where the wall meets the eave at the gable ends.

Buying Caulk

A number of sealant materials are available in easy to use forms. Most sealants are available in two consistencies: gum grade in cartridges that fit a caulking gun and used for cracks no wider than a pencil; and knife grade, applied to wider cracks with a caulking or putty knife. For very thin cracks, caulking available in hand squeeze tube may be preferred, while for very wide cracks cord or rope caulking available in rolls and easily pressed in with the fingers may be preferred. If a crack is more than 3'8" wide it will pay to stuff it with a filler such as cloth, oakum, or strips of mineral wood insulation before you caulk it.

Performance Groups

The chemical composition of sealants is important. The federal government has assigned every sealant to one of three performance groups as shown in Table 3.A. At the lowest level in the basic group are ropes, cords, and sealants based on natural oils and resins. The intermediate group consists mainly of natural or synthetic materials. The high performance group is the most expensive of the three, but in many cases well worth the extra cost. It consists of silicone, sulfide and urethane sealants. These are the most versatile of all sealants, the easiest to apply, as well as the most durable.

Application of all sealants is relatively easy if applied according to instructions on the package. (See Figure 3.4). To insure maximum adhesion it is very important that sealants be applied only to clean, dry surfaces on a warm dry day. The sealants listed in Table 3.A are all general-purpose caulks for wood, masonry, metal, and glass, but some have areas of special use as indicated in the first column. Manufacturers trade names rarely indicate the composition of a sealant. Always follow the manufacturer's instructions when applying sealants.

The information in the table can be used to match a sealant to a specific need. Adhesion is a measure of a sealant's ability to bond to a surface; shrinkage resistance measures it's ability to stay there under changing conditions. A sealant is tack-free when it loses its initial stickiness. In the curing stage it hardens and dries to its final form. For sealers that need primer, follow the manufacturer's instructions.

Inspection

Inspection of the house for caulking and weatherstripping application is a simple task requiring a few minutes time. As mentioned before, caulking is usually applied wherever two different materials or parts of the house meet. Weatherstripping is applied to windows and doors. Many of the areas that need weatherizing treatments are very obvious consisting of large cracks or gaps, but small cracks less apparent also need attention. To identify such areas a number of techniques can be employed.

1. visual inspection (check for gaps and light)
2. flame candle flicker inspection
3. draft-o-meter
4. garden hose
5. hand placed near seams of doors and windows for drafts.

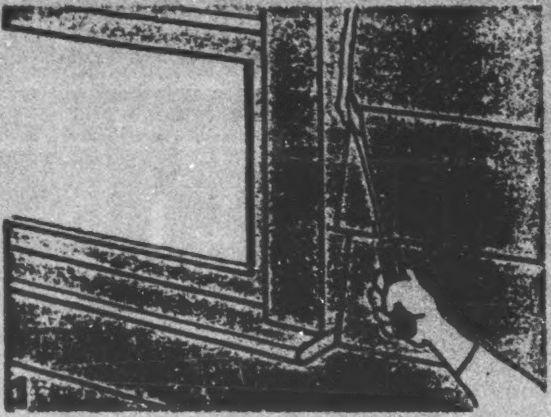
Table 3.A

Selection and Application of Various Sealants

Group*	Special Uses	Sealant	Durability (Years)	Adhesion	Shrinkage Resistance	Tack-Free (Hours)	Cure (Days)	Cleaner	Primer	Paint	Comments
Basic Performance	Glazing	Oil and Resin Caulks	1 to 7	Fair to Good	Poor	2 to 24	Up to 1 Year	Paint Thinner	Needed on Porous Surfaces	Should be Painted	Lowest cost; May stain unprimed surface
	Very wide gaps	Polybutane Cord or Rope	1 to 2	None	Excellent	Remains moist and Pliant		No cleaner required	None needed	Should not be Painted	Often used for temporary or seasonal caulks
Intermediate Performance	Indoor and protected surfaces	Nonacrylic latex; PVA	2 to 10	Good, except to metal	Fair	¼ to ½	3	Water	None needed	Optional	Deteriorates in sunlight; paint outdoor caulks
	Indoor and protected surfaces	Acrylic latex	2 to 10	Excellent except to metal	Fair	¼ to ½	3	Water	Needed on porous surfaces	Optional	Easy to apply in cool weather and on relatively damp surfaces
	Metal-to Masonry	Butyl rubber	7 to 10	Excellent	Fair	¼ to 1½	7	Naptha, paint thinner	None needed	Optional	High moisture resistance; relatively difficult to make into a neat bead
	Anywhere	Chloro-sulfonated polyethylene	15 to 20	Good	Good	24 to 48	60 to 90	Toluene, Xylene	None needed	Optional	Relatively easy to apply
	Concrete	Neoprene	15 to 20	Excellent	Good	1	30 to 60	Toluene, Xylene, Mek	None needed	Optional	Toxic; apply only when ample ventilation can be provided
High Performance	Anywhere	Polysulfide	20	Excellent	Excellent	24 to 72	7	Toluene, Tce, Mek	Neoprene primer needed	Optional	Nontoxic when cured, but may irritate skin when being applied
	Anywhere	Polyurethane	20	Excellent	Excellent	24	4 to 14	Acetone, Mek, paint thinner	None needed	Optional	Relatively easy to apply, nontoxic when cured
	Anywhere	Silicone	20 or more	Good, excellent with primer	Excellent	1	2 to 5	Naphtha, Toluol, Xylol paint thinner	Follow manu-facturer's instruc-tions	Follow manu-facturer's instruc-tions	High moisture resistance; can be applied at low temperatures; nontoxic when cured

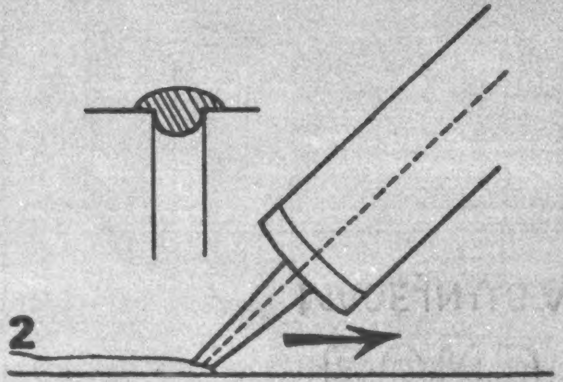
*Performance Group as assigned every sealant by the Federal Government.

Figure 2.4



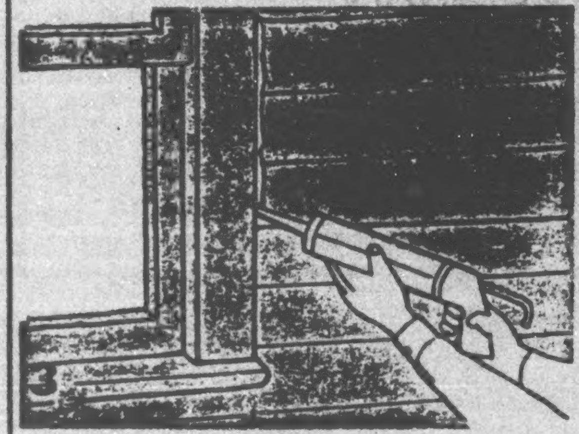
1

Before applying caulking compound, clean area of paint build-up, dirt, or deteriorated caulk with solvent and putty knife or large screwdriver.



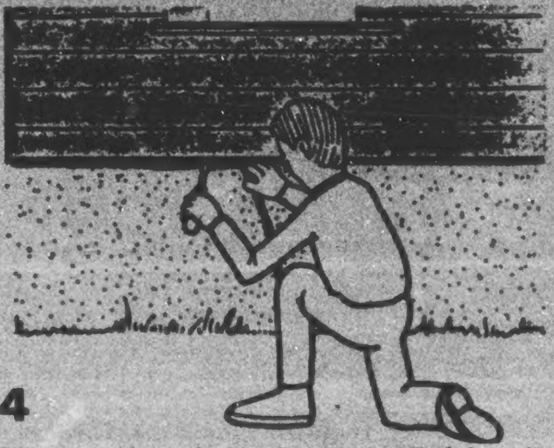
2

Drawing a good bead of caulk will take a little practice. First attempts may be a bit messy. Make sure the bead overlaps both sides for a tight seal.



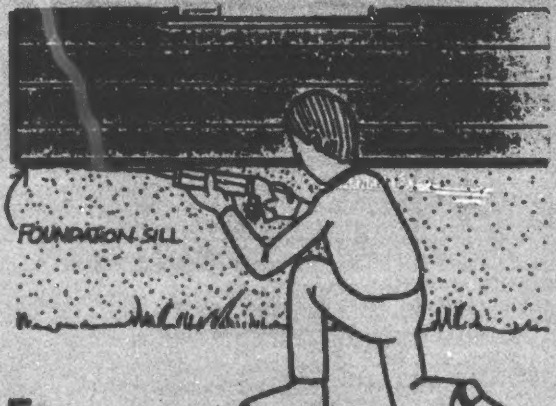
3

A wide bead may be necessary to make sure caulk adheres to both sides.



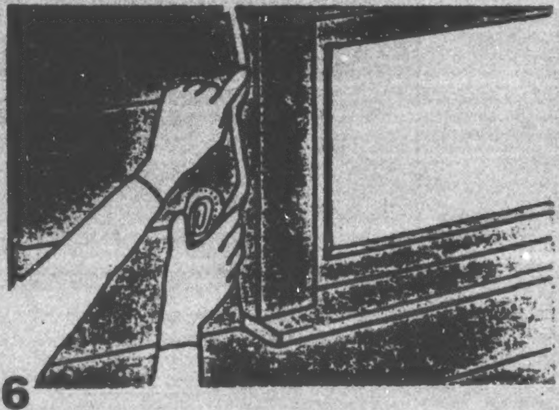
4

Fill extra wide cracks like those at the sills (where the house meets the foundation) with oakum, glass fiber insulation strips, etc.)



5

In places where you can't quite fill the gaps, finish the job with caulk.



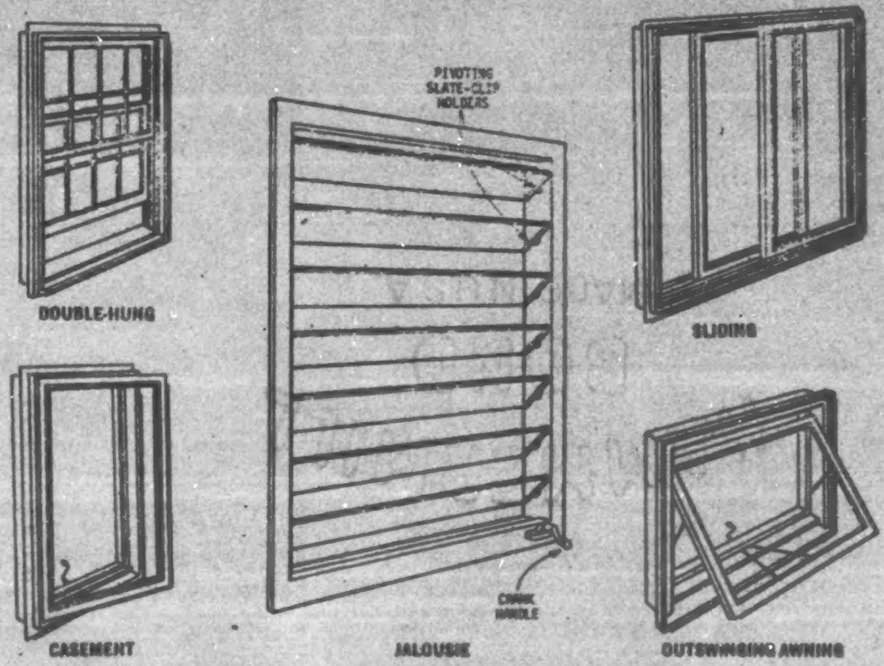
6

Caulking compound also comes in rope form. Unwind it and force it into cracks with your fingers. You can fill extra long cracks easily this way.

Whatever technique is used to identify infiltration, it is necessary that these areas be re-inspected before each heating and cooling season. Many different building materials are used in constructing houses. Because these varied materials expand and contract at different rates with changing temperatures, cracks and gaps appear which must be filled periodically.

Weatherstripping Windows

When weatherstripping, we are concerned with two basic targets: windows and doors. Materials and techniques are different in each case, so they will be treated separately. Since windows are the easiest to deal with and are the most effective heat loss treatment they will be explained first.


DOUBLE-HUNG
PIVOTING SLATE-CLIP HOLDERS
SLIDING
CASEMENT
CRANK HANDLE
JALOUSIE
OUTSWINGING AWNING

These are the five most common types of adjustable windows.

Figure 2.5 (Hand)

Unlike doors, factor-installed weatherstripping on window units has been common for years. Even so, the windows in many houses only 10-12 years old may be without this essential feature. Poor or non-existant weatherstripping can result in great amounts of heat loss or gain. In the average home approximately 46 percent of the annual heat loss is through and around glazed areas in windows and doors. Heat loss occurs through conduction and infiltration which is air flowing into the structure through cracks around the window parts.

The weatherstripping one chooses for windows will in large be determined by the type of window installed in the home. Figure 3.5 identifies the five most common types of adjustable windows and Table 3.B describes a recommended application for each.

Weatherstripping Doors

Factory-applied weatherstripping on doors is only a recent innovation. As a result, the exterior doors in millions of homes throughout the United States possess little or no weatherstripping. Most doors are installed with a space between the bottom of the door and the floor or threshold. Sometimes this space can amount to as much as one fourth of an inch or more. If weatherstripping is not used this crack allows large amounts of air to flow in and out of the house. On a typical 36 inch entry door, this small crack equals a nine square inch hole through the wall on a home.

TAPE PRODUCTS. One of the most effective and economical methods of weatherstripping doors is self-adhesive foam vinyl strips. It is on the door stop that this type of weatherstripping material is applied. The material works by being compressed between the door and the door stop. The stop derives its name from its function which is to stop the door from swinging through the upright sides of the door called the jamb. (See Figure 3.6 on the following page).

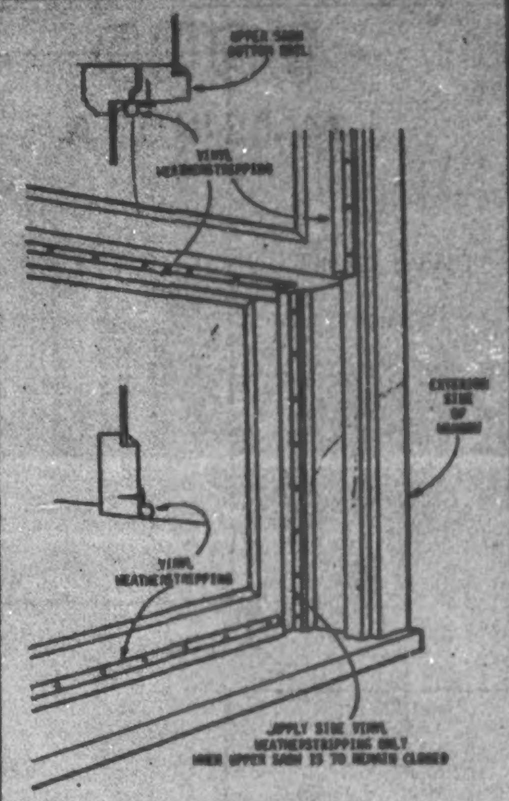
When using any form of pressure sensitive or stick-on weatherstripping, clean surfaces are a must. Any exterior door jamb is sure to have a film of dust which must be removed prior to application of the product.

NAIL ON PRODUCTS. Spring metal products have been used to weatherstrip doors. These materials are the most durable but are harder to install and often not as effective as closed-cell vinyl foam. If skilled with tools, a variety of metal weatherstripping materials can be used. Two of these are interlocking metal channels and interlocking J-strips. Both provide an excellent seal, and both are very durable. The metal channel-type is exposed during installation, and can possible be damaged then, but its the easier

Table 3.8

RECOMMENDED WEATHERSTRIPPING FOR WINDOWS

Window	Recommended Weatherstripping	Installation and Materials	Advantages/Disadvantages
Double-hung Windows	1. Tubler gasket	1. Made of rubber or vinyl plastic tube with a quarter inch to half inch lip or flange nailing.	1. Easy to install and it lasts a long time. Drawback is that is shows after installation.
	2. Spring metal	2. These strips are made of aluminum or stainless steel. They are nailed between window sash channels, between the sill and the bottom of the lower sash, and where the two sashes meet.	2. Withstands friction caused by opening and closing a window. Cannot be seen easily—blends in well. Has a long life. Difficult to install and may tend to make window difficult to open and close when first installed.
	3. Self adhesive foam vinyl strips	3. Made of neoprene rubber, vinyl, or polyurethane: Installed on double hung windows for sealing at the top and bottom sash.	3. Very easy to install. Doesn't show, controls drafts, noise, light, dust, and humidity. It will wear out almost instantly if exposed to sliding edges of a window. Foam soon flattens out and breaks down.
	4. Window channels	4. Stainless steel/aluminum construction. Comprehensive window channels can be installed to replace worn out channels or installed in old window frames without any special skills. Sash must be removed for application.	4. Eliminates sash cord or chains. Eliminates rattling. Brings old windows up to date without the expense of new windows. Installation may be difficult—sash must be removed to install.
Casement/ awning windows	Self-adhesive foam vinyl strip	Made of neoprene rubber, vinyl, or polyurethane. Adhesive-backed foam applied to the outer surface of the stopes the window butts against when it is closed.	Excellent seal for this type of window. Inexpensive and very simple to install. Foam soon flattens out under pressure.
Sliding	Essentially double hung windows turned on edge—should be treated like double-hung types, ad described above.		
Jalouise	1. Clear vinyl channel	1. Made of clear vinyl. Installed by slipping channel over the edge of each slat of glass.	1. Easy to install.
	2. Polyethylene sheet	2. Polyethylene sheet 4 mils thick. Installed by covering entire unit with sheet held in place on all sides with weatherstrip tape.	2. Stops infiltration, inexpensive, easy to install. Temporary use, and may not appear attractive.


UPPER SASH
BOTTOM RAIL
VINYL
WEATHERSTRIPPING
EXTERIOR
SIDE
OF
WINDOW
VINYL
WEATHERSTRIPPING
APPLY SIDE VINYL
WEATHERSTRIPPING ONLY
WHEN UPPER SASH IS TO REMAIN CLOSED

Rolled vinyl weatherstripping goes up with nails or thumbtacks supplied with the stripping. Apply it to double-hung windows as shown here. Note placement of the strip on the bottom of the upper sash.

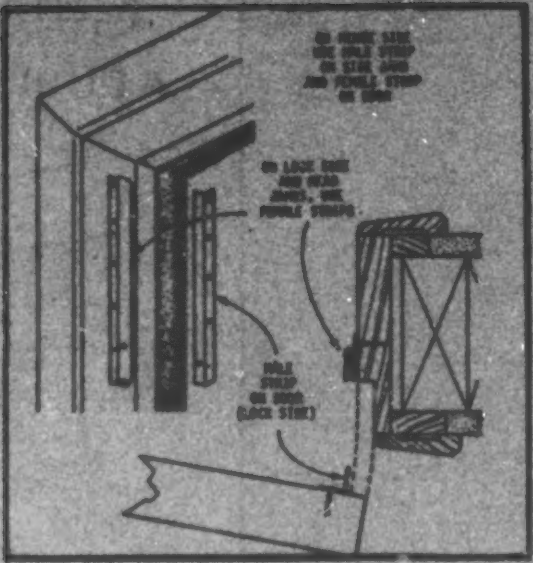
Figure 3.6 (Hand)

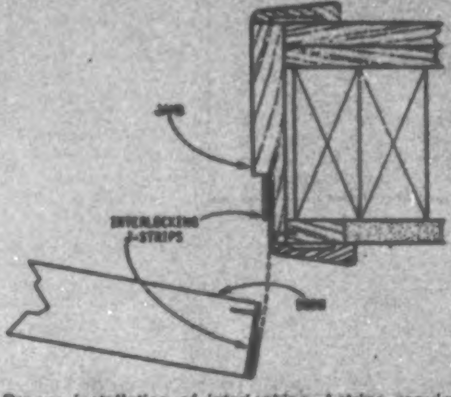
of the two to mount. Proper alignment is the only real problem. Otherwise, it is installed simply by nailing mating channels on door and jamb, following installation directions. Note that there are male and female channel strips, and that the male strip mounts on the door at the top and along the lock side but it goes on the jamb along the hinge side of the door. (See Figure 3.7).

J-strips will require removal of the door from its hinges. Then grooves are cut into the edge of the door to accept one half of the interlocking strips. The other half of the strip mounts on the jamb. (See Figure 3.8).

Another option is the bronze weatherstrip. The thin bronze strip comes in a variety of widths with one side flared out. The strip is tacked to the door jamb so when the door is closed it presses against the flared side making a tight fit.

Figure 3.7 (Hand)


ON HINGE SIDE USE MALE STRIP ON STOP JAMB AND FEMALE STRIP ON DOOR
ON LOCK SIDE AND HEAD JAMBS, USE FEMALE STRIPS
MALE STRIP ON DOOR (LOCK SIDE)


JAMB
INTERLOCKING J-STRIPS
DOOR

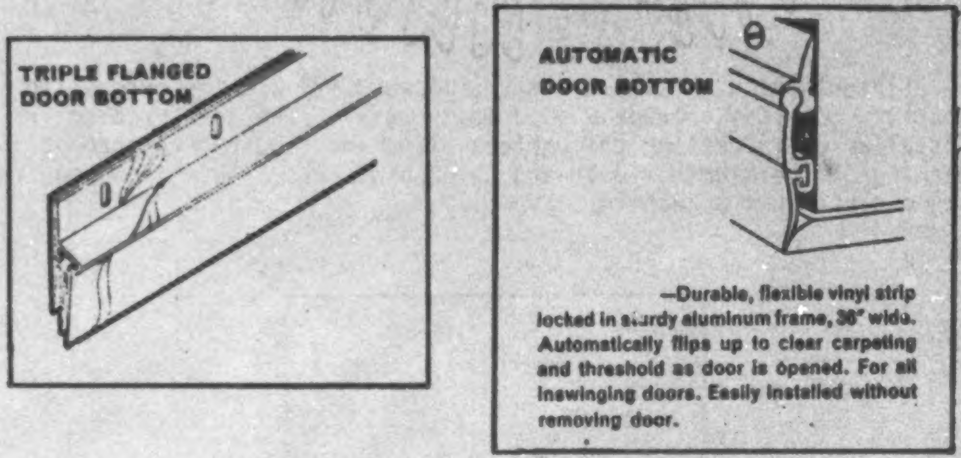
Proper installation of interlocking J-strips requires routing a rabbet in the edge of the door and jamb as shown here. This makes installation difficult but protects the stripping from damage.

Figure 3.8 (Hand)

Coiled tubing is another variety of nail-on product often used for weatherstripping. The three types most commonly used are hollow vinyl tube gasket, pre-punched reinforced hollow vinyl gasket, and neoprene coated sponge. All are installed using the same techniques. Installation is simple, requiring only a hammer, nails, and a pair of shears for cutting the material to length. For doors, the tubing is pressed against the closed door and nailed to the face of the door stop. (See Figures 3.31-3.35.)

DOOR BOTTOM. To weatherstrip the bottom of a door, there are two basic choices: sweeps and threshold strips. Door sweeps are made of felt or rubber mounted as a flap in an aluminum channel. They are easy to install and will perform very effectively if they are kept properly adjusted. Sweeps are installed by screwing the channel to the inside of the door so that the flap butts up snugly against the threshold when the door is closed. The aluminum channel usually has slots for the mounting screws so the height can be adjusted to compensate for wear.

Door sweeps can interfere with door swing if installed on a door over carpet. A fairly new stripping is mechanically operated which adjusts for such problems. This "automatic" door bottom lifts the sweep when the door is open and automatically lowers it against the floor when the door is shut. (See Figure 3.9).

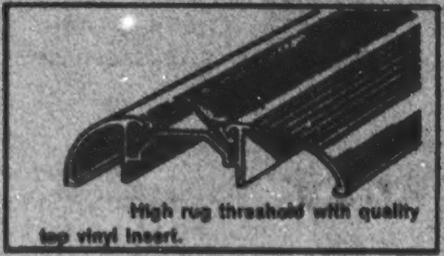


—Durable, flexible vinyl strip locked in sturdy aluminum frame, 36" wide. Automatically flips up to clear carpeting and threshold as door is opened. For all inswinging doors. Easily installed without removing door.

Figure 3.9 (W.J. Dennis & Co.)

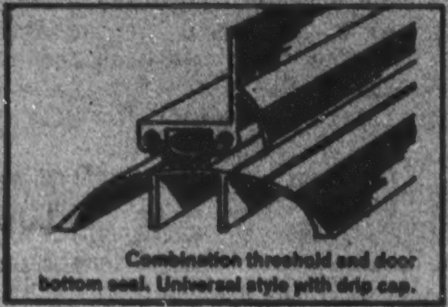
THRESHOLDS. Threshold-type weatherstripping comes in a variety of types. While most are very effective at cutting down infiltration, the average homeowner may find them difficult to install. A popular threshold is an aluminum model with the flexible vinyl "bubble." (Figure 3.10). To install this type, a certain amount of the door bottoms may have to be sawed off to provide clearance for the seal. When new, this threshold is effective, but under constant use the bubble soon collapses leaving a sizeable crack beneath the door. In most cases the vinyl is replaceable provided a dealer selling that particular model can be located.

Though not the easiest to install, the combination vinyl door bottom and aluminum threshold (Figure 3.11) is long wearing and provides effective weatherproofing. Since the vinyl is mounted in an aluminum extrusion fastened to the door, the aluminum threshold bears the brunt of wear. The one disadvantage of this system is possible frost accumulation on the threshold during extremely cold weather.



High rug threshold with quality top vinyl insert.

Figure 3.10 (W.J. Dennis & Co.)



Combination threshold and door bottom seal. Universal style with drip cap.

Figure 3.11 (W.J. Dennis & Co.)

Interlocking threshold seals (Figure 3.12) are the hardest to install, but they provide a good weatherseal. The main problem in installation is getting the perfect alignment required for proper meshing of the aluminum door and threshold parts. This type requires its own aluminum threshold.

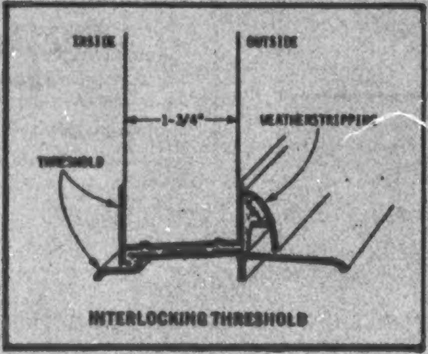


Figure 3.12 (Hand)

Door Bottoms

SWEEP - A sweep is perhaps the easiest to install. Typically it is a metal reinforced piece of plastic that you trim to door width and screw onto the face of the door at the bottom. You install it on the outside face of doors that swing out, on the inside face of those that swing in. If the predrilled screw holes are slotted, you can lower the sweep later on to compensate for wear. The sweep is quite effective, even on doors without a threshold, but its exposed to view. It may also drag across carpeting. To solve that problem, consider an automatic sweep, which retracts when the door opens and lowers again when the door closes. (See Figures 3.13, 3.14, 3.15 and 3.16.)

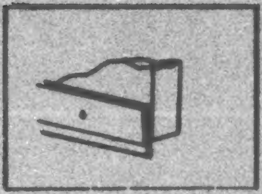
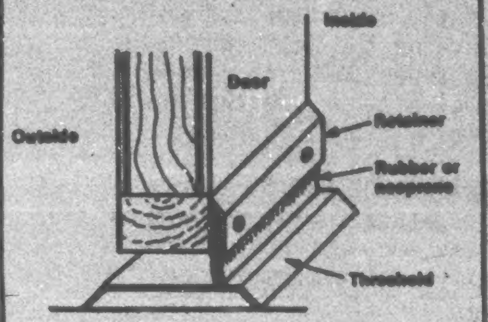
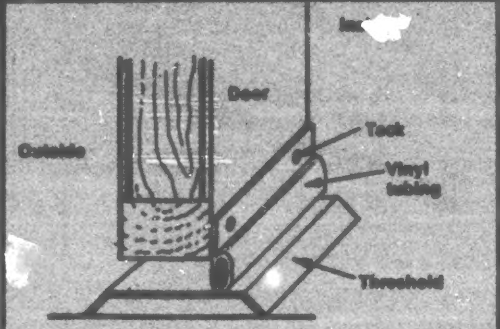


Figure 3.13a


Inside
Door
Outside
Retainer
Rubber or neoprene
Threshold

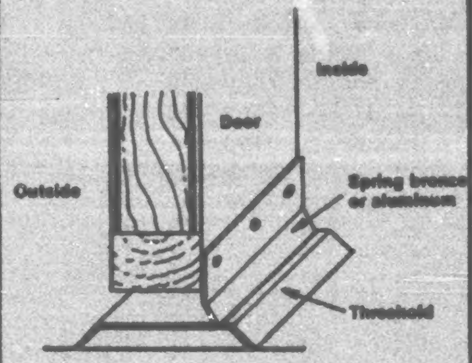
Rubber or neoprene strips seal bottom of the door and can be installed without removing the door. This seal can also be fashioned from the heavy rubber weatherstripping bead to seal around overhead garage doors or can be cut from a truck tire flap. These heavy rubber seals can be nailed directly to the door without using a retainer.

Figure 3.13b


Door
Outside
Tack
Vinyl tubing
Threshold

Vinyl tubing also allows installation without removing the door. The tubing can be bought hollow or with foam rubber in the cavity and can be tacked or stapled to the door.

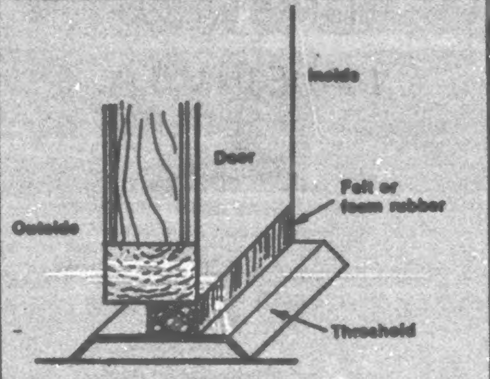
Figure 3.14


Inside
Door
Outside
Spring bronze or aluminum
Threshold

Metal strips are spring bronze, aluminum, and stainless steel.

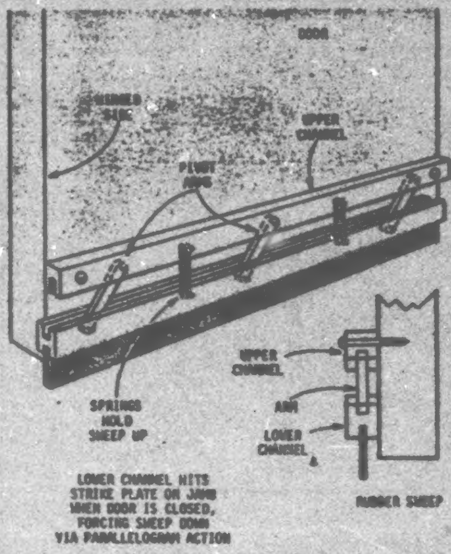
(doors must be removed for installation and made parallel with sill; metal may scratch floor).

Figure 3.15


Inside
Door
Felt or foam rubber
Outside
Threshold

Felt or foam rubber strip may be attached to bottom of the door. The strip can be tacked or stapled. Foam rubber strips can also be bought with self-stick backing. While this may be the cheapest material, it requires removal of the door.

Figure 3.16


DOOR
FINISHED SIDE
UPPER CHANNEL
PIVOT ARMS
UPPER CHANNEL
ARM
LOWER CHANNEL
SPRINGS HOLD SWEEP UP
LOWER CHANNEL HITS STRIKE PLATE ON JAMB WHEN DOOR IS CLOSED, FORCING SWEEP DOWN VIA PARALLELOGRAM ACTION
RUBBER SWEEP

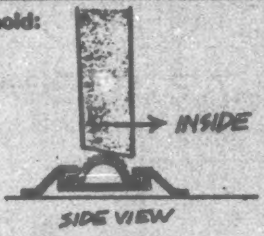
This automatic door sweep is spring loaded to rise above carpet level whenever you open the door. Closing the door forces the end of the sweep against a strike plate on the jamb, which forces the sweep downward, producing a tight seal between the threshold and the sweep.

Figure 3.17 (Hand)

AUTOMATIC DOOR SWEEP - The "automatic" door sweep is spring loaded to rise above carpet level whenever the door is open. Closing the door forces the end of the sweep against a strike plate on the jamb, which forces the sweep downward, producing a tight seal between the threshold and the sweep. (See Figure 3.17).

SPONGE RUBBER DOOR BOTTOM SEAL - Mainly for garage doors, a blend of high quality sponge rubber that stays flexible at extremely low temperatures. Applied to bottom of door with wide lip outside, except wide lip would be inside if garage is lower than driveway.

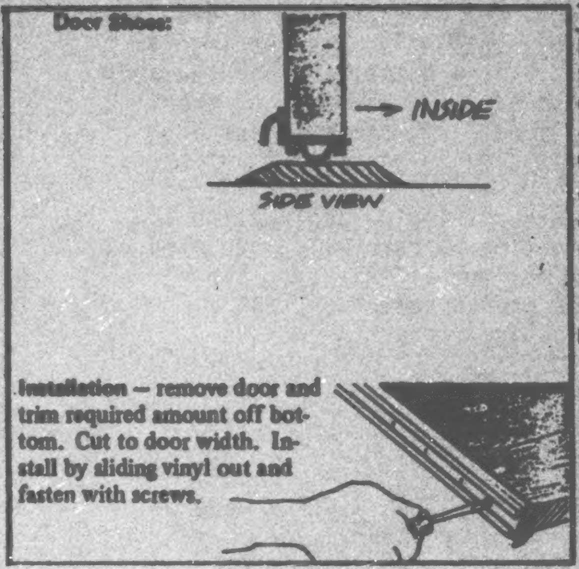
Vinyl bulb threshold:


INSIDE
SIDE VIEW

Installation — remove door and trim required amount off bottom. Bottom should have about 1/8" bevel to seal against vinyl. Be sure bevel is cut in right direction for opening.

Figure 3.18

GASKET THRESHOLD/VINYL BULB THRESHOLD - These replace existing thresholds or provide a threshold where there is none. They are essentially metal moldings with a broad vinyl hump running along their top face: the closed door compresses the hump and makes the seal. Various heights are available. The gasket thresholds seal well, but they leave the gasket exposed to foot traffic that will eventually reduce the effectiveness of the seal. You will then have to replace the gasket, which is usually an easy job. (See Figure 3.18).

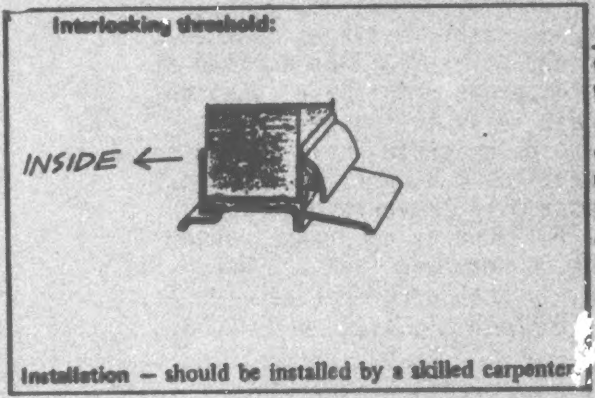


Door Shoes:

Installation — remove door and trim required amount off bottom. Cut to door width. Install by sliding vinyl out and fasten with screws.

Figure 3.19

TWO PIECE DOOR SHOE - A more protective installation is the two piece door shoe. The shoe, with its gasket, slips over the bottom of a door, where its protected from the wear and tear of foot traffic. As a bonus, these shoes often include a "drip cap" that sheds rain. The door shoe can be used with any threshold that isn't worn down in the middle. The gap under the door must be large enough to allow installation of the shoe. If it isn't, you will have to remove the door and trim it for the extra clearance. The slotted screw holes, through which you attach the shoe, allow some margin for adjustment. (See Figure 3.19).



Interlocking threshold:

Installation — should be installed by a skilled carpenter.

Figure 3.20

INTERLOCKING THRESHOLD - Very difficult to install, exceptionally good weather seal. The main problem in installation is getting the perfect alignment required for proper meshing of the aluminum door and threshold parts. This type requires its own aluminum threshold. (See Figure 3.20).

WEATHERSTRIPPING GARAGE DOORS. Overhead garage doors can also provide a large source of infiltration. A one-eighth inch crack around the average single garage door yields almost 50 square inches of area--enough to be concerned about especially if the garage is attached to the house.

"Garage door bottom" weatherstripping is available in rubber or vinyl. The door bottom is simply cut to measure and nailed to the bottom edge of the door with rust resistant nails.

Installation of an overhead garage door weatherstrip is also a good investment. One brand uses a vinyl leaf which fastens into an aluminum frame. Installation requires only a hammer and hacksaw and is accomplished by nailing the aluminum strip to the face of the door stop allowing the vinyl leaf to "float" against the face of the garage door.

OTHER APPLICATIONS. Whatever weatherstripping application is needed, it is necessary that each situation be carefully inspected and the correct selection be made for maximum efficiency. The following pages will aid in making the proper selection with a description of the material and application.

Other Types & Applications

SELF-ADHESIVE FOAM STRIP - made of neoprene rubber, vinyl, or polyurethane with paper or vinyl backing in thickness up to 3/8" and widths up to 3/4". Backing is peeled off as tape is pressed in placed on door and window jambs, stops, or sash. Surfaces must be clean and dry; should be applied at room temperature for best adhesion. Low cost, easy to install; foams tend to deteriorate when exposed to weather, may last only one season. The most durable variety is vinyl foam, followed by neoprene sponge, sponge rubber, and foam polyurethane, in that order. (See Figures 3.21, 3.22, 3.23, 3.24, and 3.25).

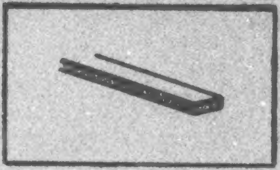


Figure 3.21

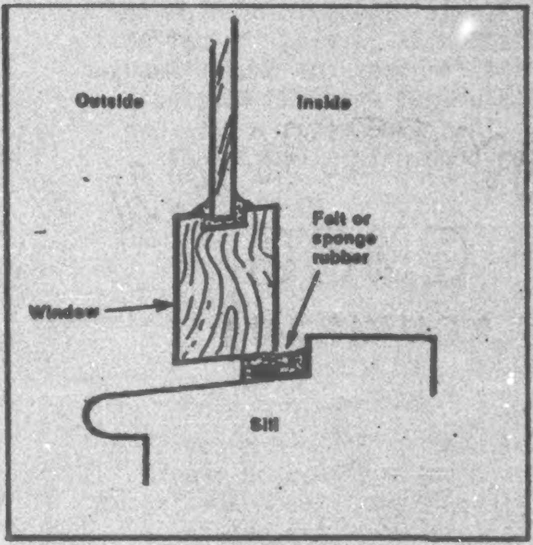


Figure 3.22

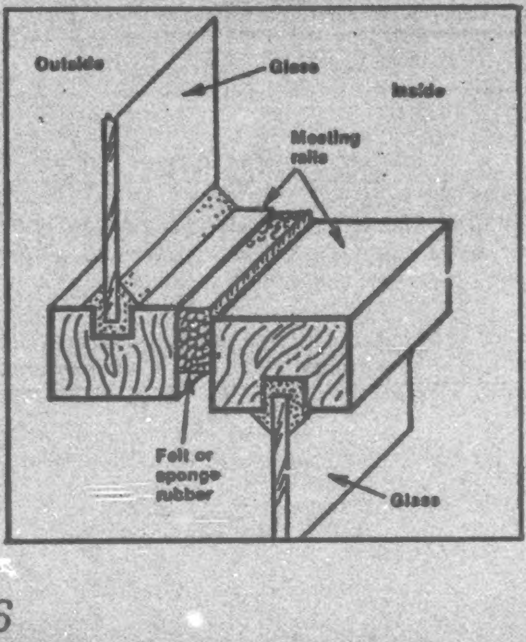


Figure 3.23

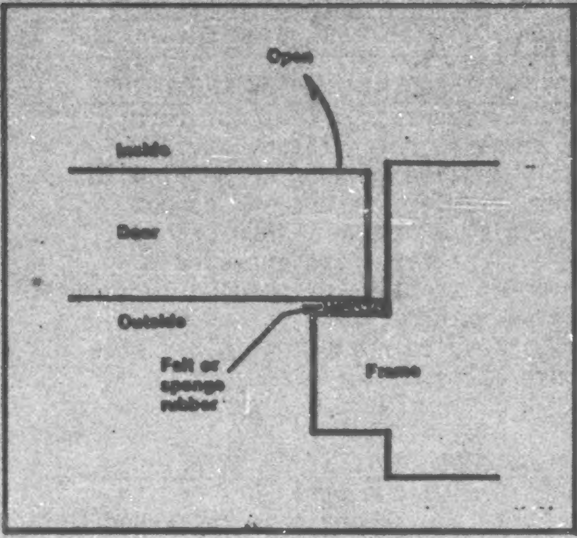

Open
Inside
Door
Outside
Felt or sponge rubber
Frame

Figure 3.24

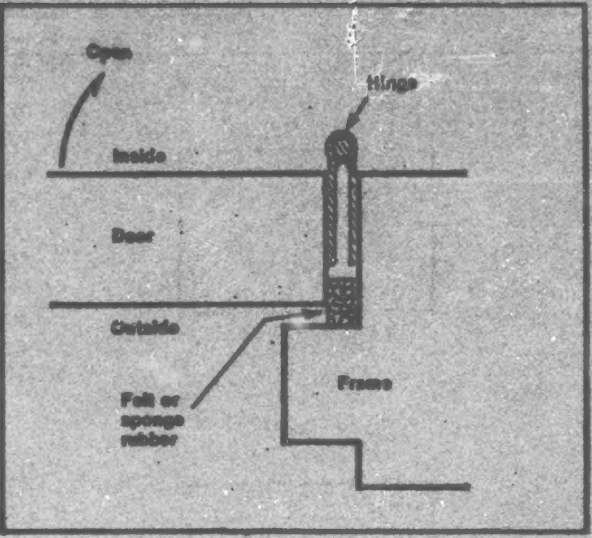

Open
Hinge
Inside
Door
Outside
Felt or sponge rubber
Frame

Figure 3.25

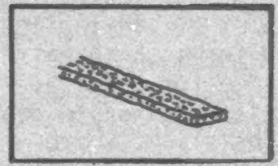


Figure 3.26

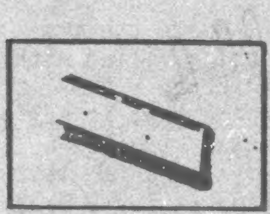


Figure 3.27

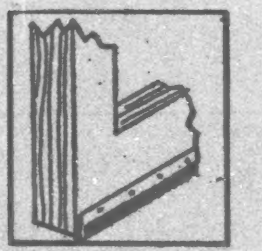


Figure 3.28

NONREINFORCED FELT WEATHERSTRIP - Low cost material found in strips up to 3/8" thick and some 5/16 to 1-1/4" wide. Fasten to wood by tacking or stapling and to metal with a good adhesive. Must be applied to door stop or jamb and window stop, sill or sash so it fits snugly against the other member, Easy to apply, vulnerable to abrasion, weather and tears easily during use, not as effective when wet. (See Figure 3.26).

ALUMINUM AND FELT STRIP/REINFORCED FELT - Felt which has been reinforced by aluminum. It is best used where little abrasion is expected--on a door stop or the bottom of a window, for example, but not at the side of a window, where it would be rubbed when the window is opened and closed. It's also best not be expose felt fully to the weather, since fungi, insects, and moisture can attack the felt. Felt may tear during normal use, especially on doors; felt not as effective when wet. (See Figures 3.27 and 3.28).

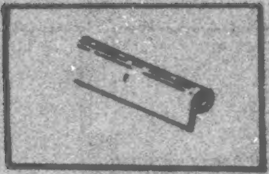


Figure 3.29

__VINYL WEATHERSTRIP/HOLLOW VINYL TUBE GASKET__ - General purpose moisture and temperature resistant strip easily applied to wood or metal with tacks, staples, screws, or a good commercial adhesive. Tube shaped for a tight fit, with extended strip for stapling or bonding to door and window jambs, stops or sash. Easy to apply; durable. (See Figure 3.29).

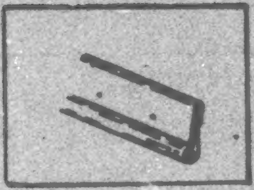


Figure 3.30

__ALUMINUM AND VINYL STRIP/REINFORCED GASKET__ - Aluminum strip crimped to vinyl strip with one edge thickened for snug fit between the two members allowing for expansion and contraction of members. Durable, fairly easy to apply on door and window jambs. (See Figure 3.30).

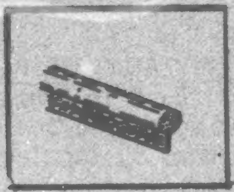


Figure 3.31

__TUBULAR GASKET/SPONGE RUBBER NEOPRENE COATED STRIP__ - Tubular gasket is basically a rubber or vinyl plastic tube with a quarter inch to half inch lip or flange for nailing. Tubular gasket is attached to door stops so that the slightly protruding tube is compressed when the door is closed. On double hung windows, it is nailed at the sides to the window frame, at the top and bottom to the rails of the sashes, and at the joint where the two sashes meet. Tubing filled with polyurethane or sponge rubber is preferred to tubing that is hollow. Tubing with flanges strengthened with wire or paper cord may last longer. (See Figures 3.31, 3.32, 3.33, 3.34 and 3.35).

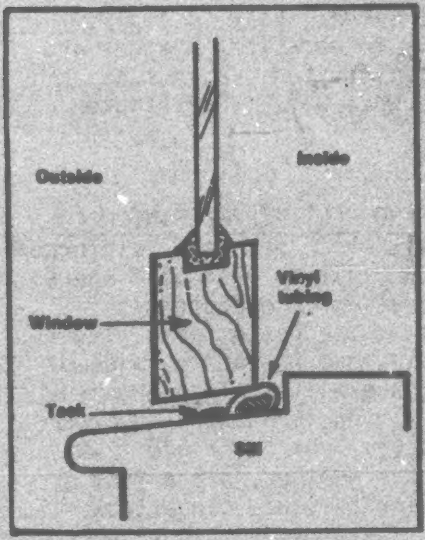
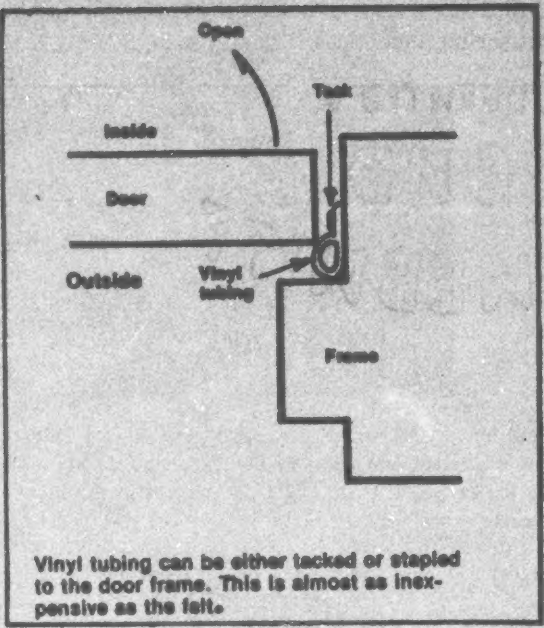


Figure 3.32


Open
Tack
Inside
Door
Outside
Vinyl tubing
Frame

Vinyl tubing can be either tacked or stapled to the door frame. This is almost as inexpensive as the felt.

Figure 3.33

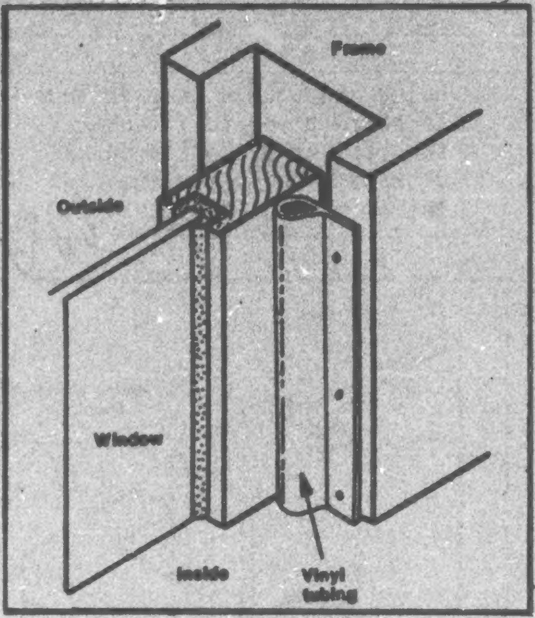

Frame
Outside
Window
Inside
Vinyl tubing

Figure 3.34

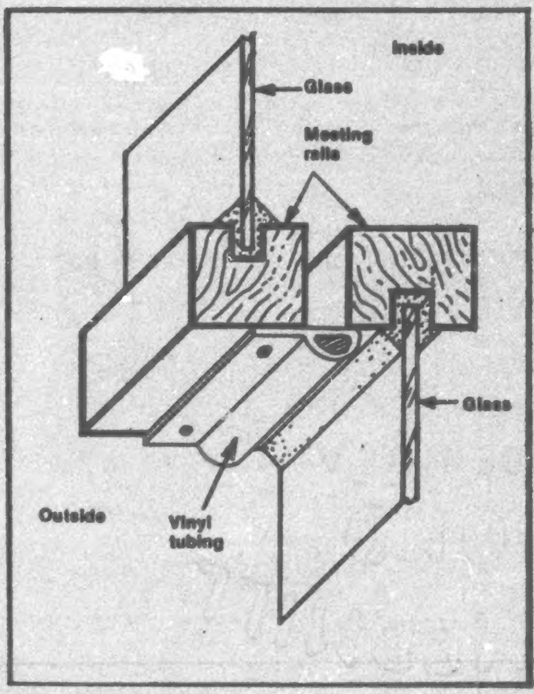

Inside
Glass
Meeting rails
Glass
Outside
Vinyl tubing

Figure 3.35

METAL WEATHERSTRIPS - If metal strips are correctly installed, they can be highly efficient. They come as flat "tension" strips, sold in rolls. One edge of the strip is nailed to a door or window frame then the free edge is lifted away from the frame. That develops a spring tension which holds the strip against the door or window when it's closed. The metal strips are not really difficult to install. For doors they go inside the door jamb at the top and on the side. For double hung windows, they go inside the side channels as well as at the top of the upper sash, the bottom of the lower sash, and where the two sashes meet. Awning (top-pivoting), hopper (bottom-pivoting), and casement windows are treated as doors are. Windows that slide horizontally can be considered double hung windows on their sides. Properly installed, metal weatherstripping is practically invisible. Look for strips with predrilled nail holes and brands that include an extra piece to fit over the striker plate (if for a door) and nails for installation. (See Figures 3.36, 3.37, 3.38 and 3.39).

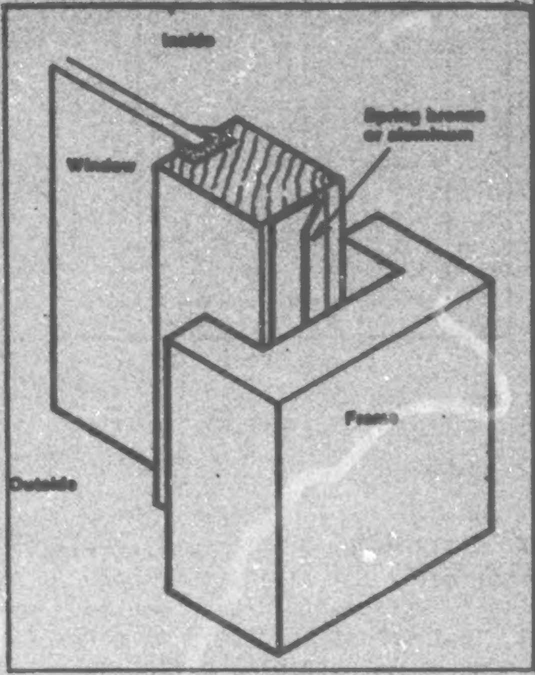

Inside
Spring bronze or aluminum
Window
Frame
Outside

Figure 3.36

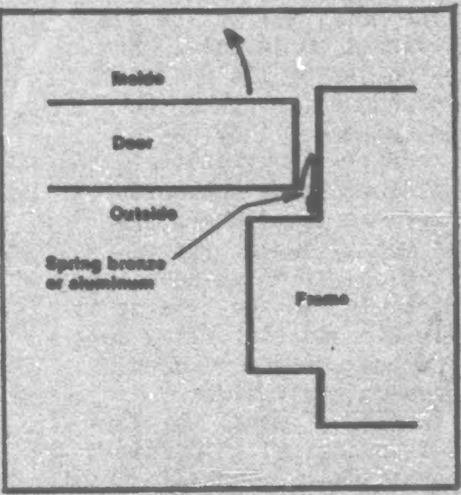
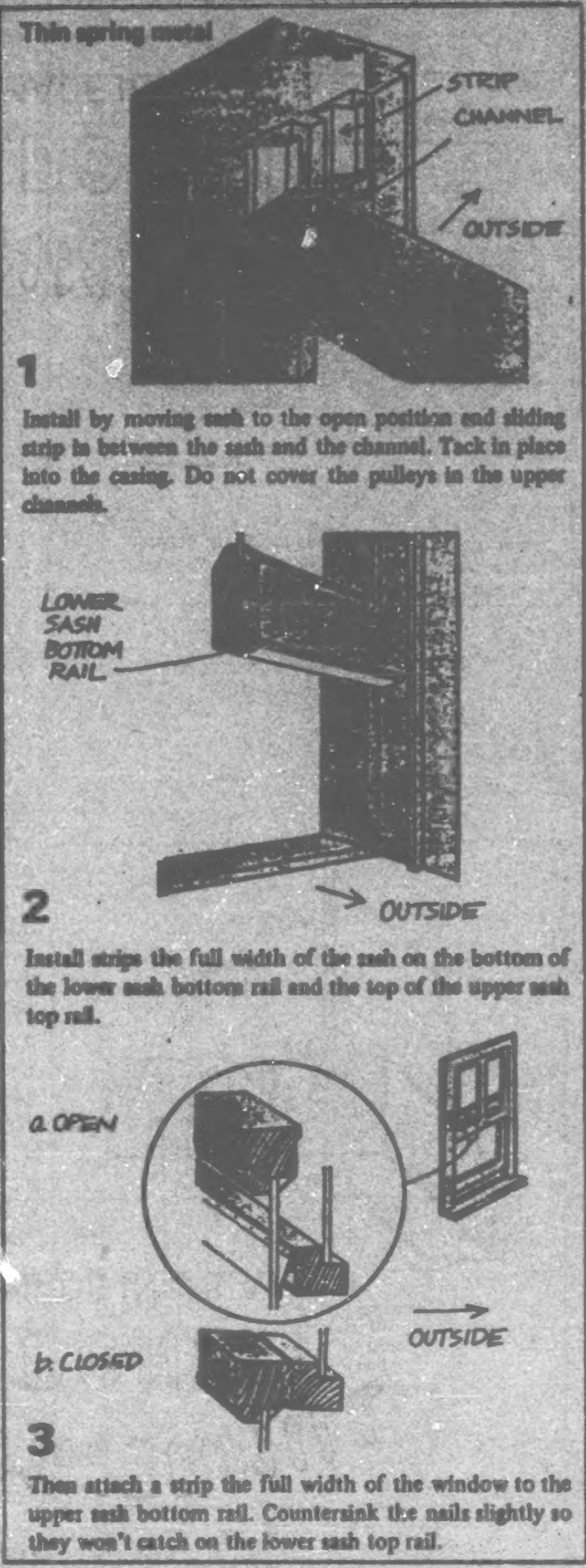

Inside
Door
Outside
Spring bronze or aluminum
Frame

Figure 3.37


Thin spring metal
STRIP
CHANNEL
OUTSIDE
LOWER SASH BOTTOM RAIL
OUTSIDE
a. OPEN
b. CLOSED
OUTSIDE

1

Install by moving sash to the open position and sliding strip in between the sash and the channel. Tack in place into the casing. Do not cover the pulleys in the upper channels.

2

Install strips the full width of the sash on the bottom of the lower sash bottom rail and the top of the upper sash top rail.

3

Then attach a strip the full width of the window to the upper sash bottom rail. Countersink the nails slightly so they won't catch on the lower sash top rail.

Figure 3.38

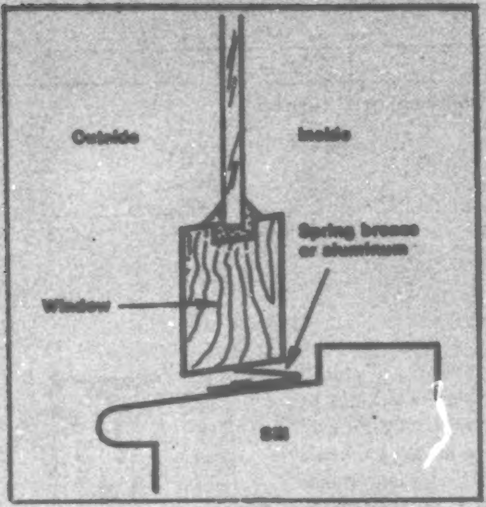


Figure 3.39

WATERPROOF WEATHERSTRIP TAPE - Self-sealing transparent, durable poly tape for sealing cracks in any location. Easy to use by pressing to a clean and dry surface. For windows, tape applied half on stop and half on sash. (See Figure 3.40).

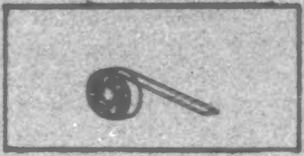


Figure 3.40

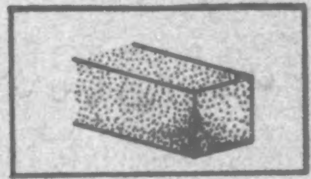


Figure 3.41

AIR CONDITIONER WEATHERSTRIP - Rectangular poly foam that press fits between the top frame of lower sash and upper pane to seal off the air spaces between window and air conditioner. Low cost, easy to install. (See Figure 3.41).

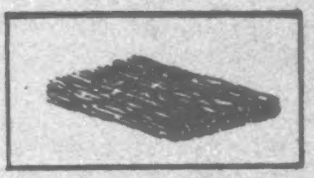


Figure 3.42

FIBER GLASS INSULATION STRIP - Insulation strip in various sizes' used with waterproof tape for closing large cracks around basement and garage doors, windows, and other cold air leaks. Also wrapped around hot water pipes for insulation. (See Figure 3.42).

WINDOW CHANNELS - Excellent for double-hung windows that are old, loose in their channels so they rattle in the wind, unweatherstripped, and otherwise on the brink of becoming obsolete. Channel modernizes the window by eliminating sash cords or chains. Installation involves prying off the parting head and removing old sash. (See Figure 3.43).

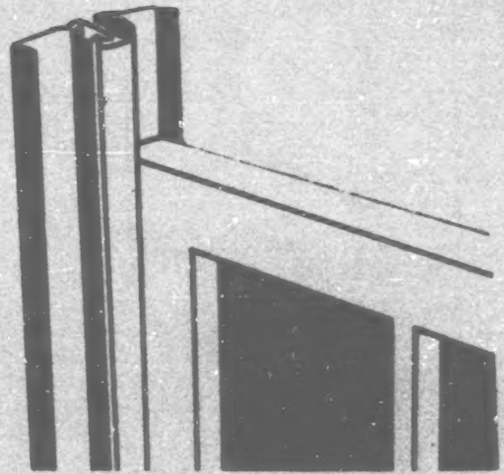


Figure 3.43

INTERLOCKING METAL CHANNELS - Difficult to install (alignment is critical), visible when installed, durable but subject to damage because they are exposed. Excellent seal. Interlocking metal channels must be aligned properly for proper mating of male and female strips. Do the head of the door first, nailing the male strip to the door and the strip to the door frame. On the hinged side, of the door mount the female strip on the door; the male strip on the jamb. Do the lock side of the door last, male strip on the door; female strip on the jamb. (See Figure 3.44).

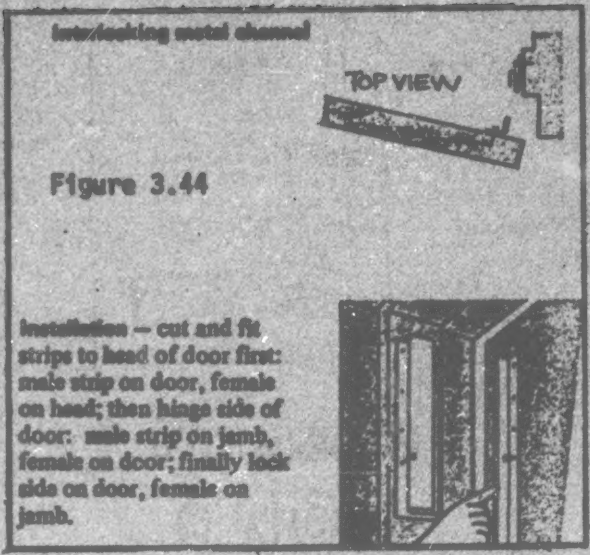


Figure 3.44

Installation — cut and fit strips to head of door first: male strip on door, female on head; then hinge side of door: male strip on jamb, female on door; finally lock side on door, female on jamb.

FITTED INTERLOCKING METAL CHANNELS- (J-strips) - Very difficult to install, exceptionally good weather seal, invisible when installed, not exposed to possible damage. Proper installation of interlocking J-strips requires routing a rabbet in the edge of the door and jamb. (See Figure 3.45).

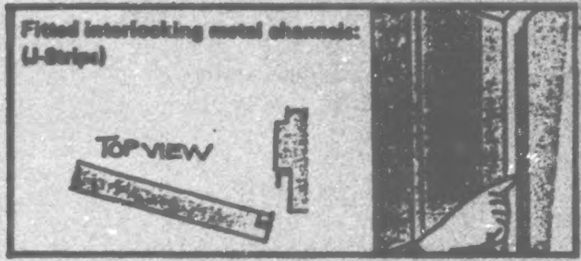


Figure 3.45

RIGID STRIPS - This type has resiliant strips, such as plastic foam or a tubular gasket, that comes preattached to wood or aluminum moldings. That, in turn, nails or screws to wood or aluminum door jambs, respectively. The strips are primarily for use on door frames and usually come in a kit that contains two long pieces for the sides of the jamb and a shorter piece for the top. (See Figure 3.46).

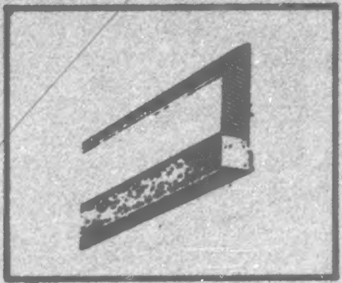


Figure 3.46 (W.J. Dennis & Co.)

Throughout the year window model air conditioners are notorious fuel consumers. To eliminate infiltration around the unit make sure all exterior case and window joints are properly caulked or sealed. After the cooling season be sure to wrap the unit with a manufactured air conditioner cover or make one using polyethylene plastic.

For those with window units in a second story window, the treatment should be applied from the inside. Using polyethylene and transparent weatherstrip tape, cover the front of the unit by taping the plastic to the inside window casing.

A final area of air conditioner related infiltration is the crack which develops between the raised sash of a double-hung window. Ordinary fiberglass insulation can be used to fill this void, but a more attractive solution is a strip of specially sized urethane foam.

SECTION III

Windows and Doors

Windows lose a lot of heat. Even if they are well weatherstripped, made of insulated glass, or if they're fitted with storm windows, you can expect them to lose 6 to 10 times as much heat as an insulated wall of the same area. According to recent Department of Energy publications, one-fourth of the energy used in the United States each year to heat and cool residential and commercial buildings is wasted because of unwanted heat gains and losses through windows. This energy loss amounts to about 5 percent of the total U.S. energy consumption and is equivalent to 1.7 million barrels of oil per day. Heat loss and gain through windows represents a significant financial burden for the consumer; between $0.40 and $1.40 is added to fuel bills each year for every square foot of window area where a standard single pane window is used. (For heat loss calculations see Unit 2).

Storm Windows

There are many ways to reduce heat loss through windows, such as installing storm and double-pane windows--methods which have been used for many years. The primary purpose of storm windows is to provide a buffer of dead air space between the inside warm temperature and the outside colder temperature in winter. While the opposite conditions exist during the cooling season, the buffer, of course, is needed in hot weather also. In fact, this buffer of air space helps overcome problems that are of concern to a home's occupants.

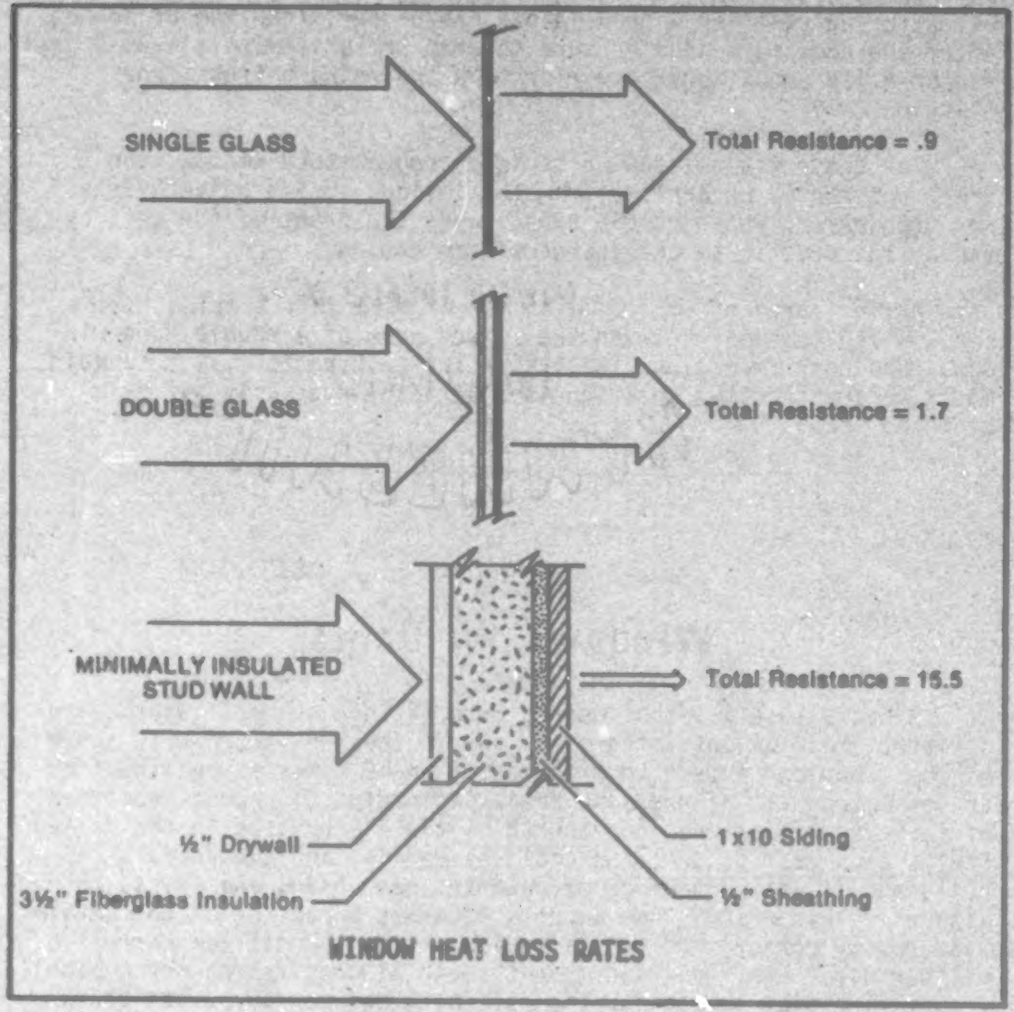

SINGLE GLASS
Total Resistance = .9
DOUBLE GLASS
Total Resistance = 1.7
MINIMALLY INSULATED STUD WALL
Total Resistance = 15.5
½" Drywall
3½" Fiberglass Insulation
1x10 Siding
½" Sheathing
WINDOW HEAT LOSS RATES

Figure 3.47 (Eccl1)

First. An air space helps to reduce heat loss. A single-glazed wood window with an 80% glass area has a winter "R"-value of .980. "R" indicates the ability of material to resist heat. The larger the "R", the better the insulating value. ("U" value is a reciprocal of R). If the insulating glass with a one half inch air space were specified instead, the "R" value of the window would be 1.81, an increase of almost 50 percent. This improvement results not so much from the additional glass but from the trapped air which is a relatively good insulator. Adding storm windows to single-glazed wood windows takes advantage of the same principle and can increase the R-value to 2.00. If the storm window is applied to a wood window with insulating glass, the R-value would be only 2.94, a 67 percent increase compared to a single glazed wood window alone. Multiple glazing can reduce heating costs by 10 to 20 percent.

Second. Storm windows help reduce condensation on the inside windows by allowing the temperature of the air next to the inside glass to remain higher, and hence, not condense the moisture in the air.

Third. Storm windows can reduce the wear and deterioration of the painted window frame and sashes.

Storm Window Options

There are several different kinds of storm windows. The cheapest way to have storm windows is simply to use plastic sheeting. Although their life is limited, a plastic storm window is as good an insulator as a sheet of glass when installed properly. Four or

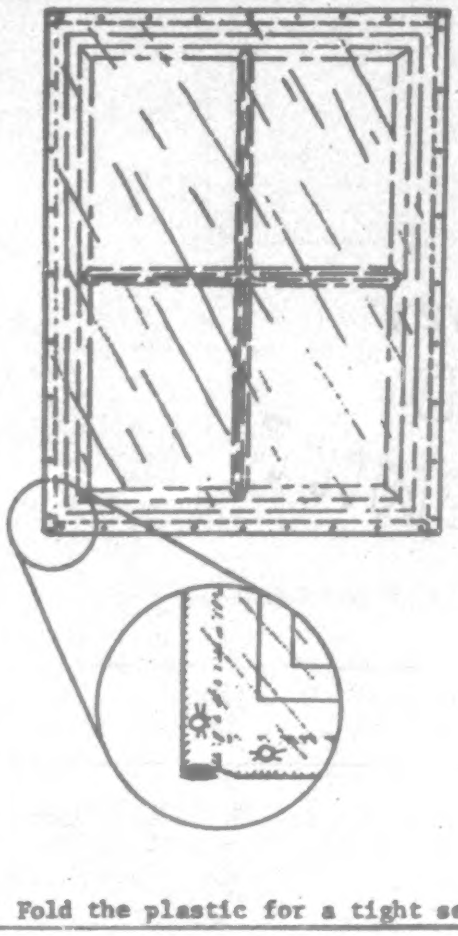
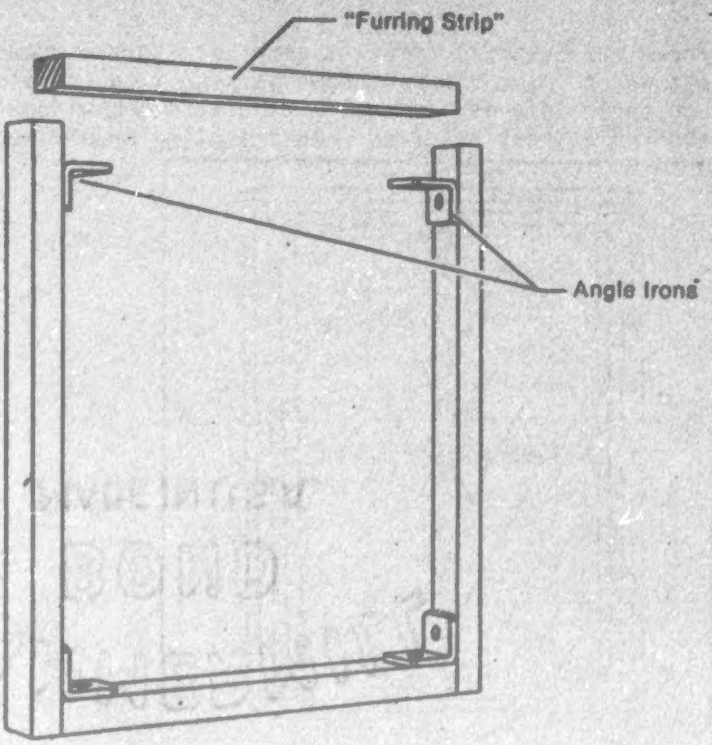


Figure 3.48

Fold the plastic for a tight seal

six-mil polyethylene is available at just about any building supply outlet both in rolls and in "storm window" lots. In order to save a few cents and get sheets large enough for any windows, the plastic in the roll is the best buy. The plastic should be cut to size slightly larger than the window frame. The edges are then rolled in a thin strip of cardboard and tacked or stapled to the window frame. (See Figure 3.48). This type of storm window will normally last one year.

To extend the life of the plastic and make counting the plastic easier, frames can be made from wood furring strips, attached at the corners with small angle irons. (See Figure 3.49). The storm frame should be made to just fit into the window frame. After the plastic is stapled to it, the frame is attached to the window opening with screws.



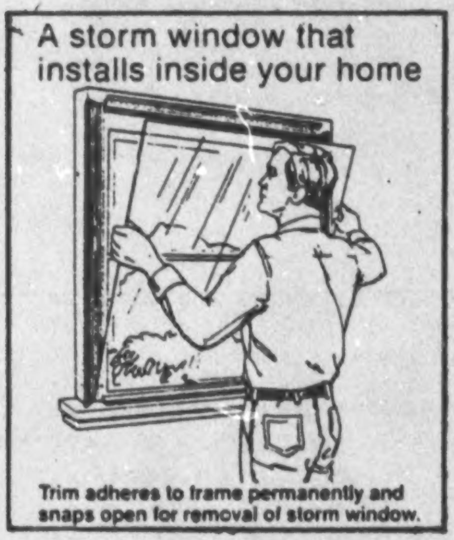
Plastic Storm Frame

Figure 3.49 (Eccli)

In order to reach areas such as upper floors of a home, plastic windows can be installed on the inside. The plastic can be attached to the frame with weatherstripping or duct tape. (Use caution when removing tape--it may take the paint with it). Attached to the inside, the plastic storm will last longer and will not detract from the appearance of the home exterior. The cost of the different plastic storm windows varies, but they should not cost over about $.50 per window.

A second kind of storm window that is often used is a single piece of glass or rigid plastic that is attached to a frame. They usually hang in place, can't be opened, and have no screens. The cost of one of these is approximately $10.00, depending on how elaborate the frames are. If the home has air conditioning or for some other reason the windows never need to be opened, this type of storm can be left in place year round, saving on both heating and cooling. Otherwise, they can be put up in the fall and taken down in the spring, and replaced with screens. This can be a bit troublesome, at least on upper floor windows and with storage.

For interior installation of the glass or rigid plastic storm, a number of manufacturers offer kits that can be taken down with each season or left in place. As seen in figure 50 on the following page, the trim adheres to the interior permanently and snaps open for installing and removal of storm windows.


A storm window that installs inside your home
Trim adheres to frame permanently and snaps open for removal of storm window.

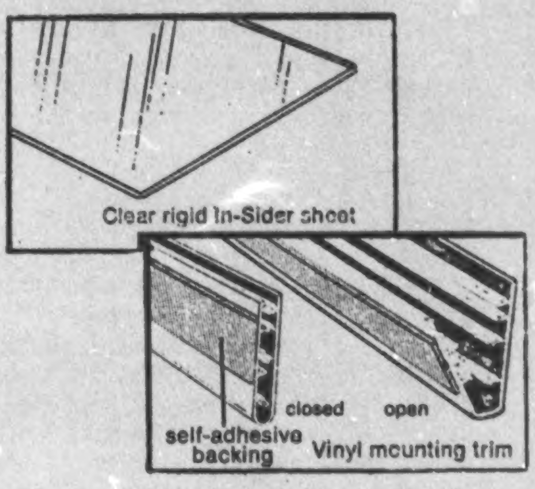

Clear rigid In-Sider sheet
closed
open
self-adhesive backing
Vinyl mounting trim

Figure 3.50 (Plaskolite, Inc.)

The third type of storm windows most commonly used is the permanent type double-track or triple-track window and screen combination. As with any product in any industry, there are types that range from poor to excellent. Keep in mind that all these storm windows offer about the same amount of environmental control; the big difference is in how easy they are to operate, clean and maintain, and how easily they can be serviced.

Storm windows that are referred to as triple-track have a separate track for each sash and for the screen. This gives the home occupant the choice of placing the screen at the top or bottom location as well as allowing for ventilation from top or bottom of the window during the warmer seasons. These features are not important as they are made to sound, as the need to raise a screen or lower the screen is not that important. The only time a screen is moved is to place something in or through the window, and this rarely happens.

Storm windows that are referred to as double track have a fixed upper window and a fixed lower screen in the outside track and a movable window in the inside track. In most cases, all three frames can be removed completely for repair or cleaning.

The combination storm window can cost anywhere from $15 to $30 for the average window, depending on overall quality of construction and materials.

Interior Window Treatments

There are a variety of improvements that can be made to the inside of the home which will also upgrade the energy efficiency of the windows. Shades, draperies, insulating shutters, and heat-absorbing surfaces can all be put to work to cut heating in the winter and cooling costs in the summer.

Shade Against Summer Heat Gain

Shading windows during the summer can eliminate the need for air conditioning during much of the cooling season and drastically reduce the load on the air conditioner when it is required. Shading is most effective if it occurs outside the windows. If a window is totally shaded and air can circulte between the shading device and the glass, solar heat gains can be reduced by 80 percent. Examples of effective external shading devices includes canvas awnings, operable shutters (the lowered type permits concurrent shading and ventilation), commercial "solar screens" (a series of closely spaced aluminum slots), and not be forgotten traces (deciduous species do not shade the winter sun). Shading can also be accomplished architecturally as with roof overhangs or trellises, if possible, designed to admit the winter sun, which lower on the horizon through the summer sun.

Drapes, blinds, or roll shades inside the window are less effective because they solve the problem after the sunlight has already entered the house. However, much of the sunlight can still be reflected out instead of being converted to heat inside the room. Some examples of shading devices and the percentage they reduce solar heat gain are given below.

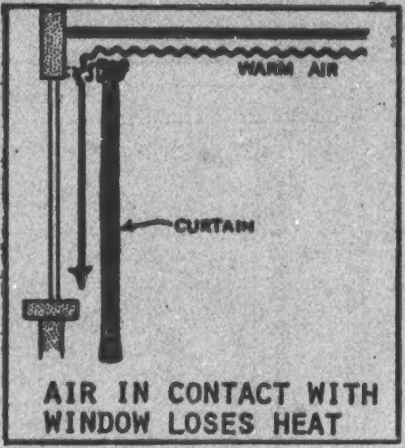
Device	Reduction
White Opaque roller shade	50%
White lined drapery	33%
Venetian blind (slats 45)	18%
Venetian blind (closed)	29%
White translucent roller shade	44%

Draperies

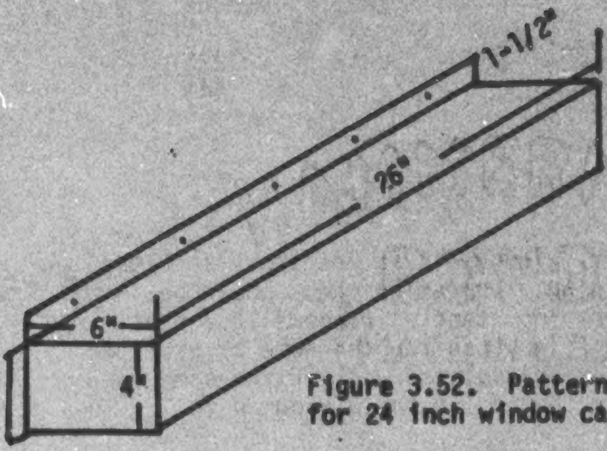
To make the best use of sunny windows it is necessary to close them off when the sun is not shining. Draperies then should be closed off at night. This is very important as windows lose heat to the out-of-doors very quickly. They can rob the home of heat two to three times faster then even as uninsulated wall of the same size. So, when the sun goes down, button up the windows with draperies.

Good window draperies will help save money. They reflect heat back into the house and keep air away from the cold windows. To do this, the drapery must be tight at the top and sides. Otherwise, the warm air of the ceiling will move down the walls and windows as it cools. (See Figure 3.51).

Figure 3.51 (Eccli)



To make a drapery more effective the air circulating in the room must be stopped from going down across the cool glass and onto the floor. One way to cut down on this convection flow is to put a cardboard or plywood box (see Figure 3.52 for pattern) over the top of the curtain (see Figure 3.53 on the following page). This prevents warm ceiling air from moving down across the glass, but a local convective air flow still develops. To eliminate this flow the drapery must be sealed to window frame on the bottom and sides which will hold cold air inside the formed pocket. A few materials such as hooks, snaps, Velcro, or any other mechanical fasteners can be used on draperies. Many of these treatment devices can be located at local hardware and yardgoods stores.



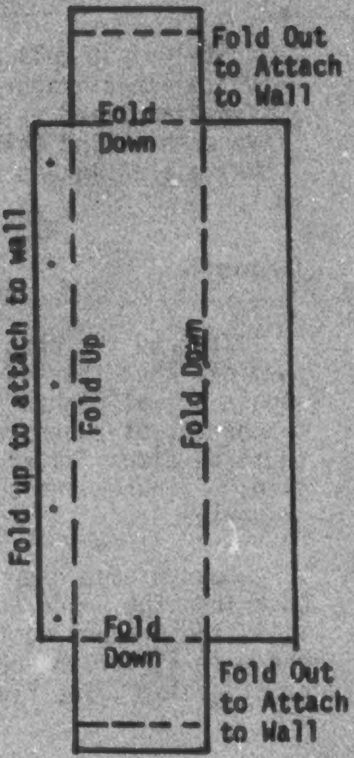

Fold Out to Attach to Wall
Fold Down
Fold up to attach to wall
Fold Up
Fold Down
Fold Down
Fold Out to Attach to Wall

Figure 3.52. Pattern for 24 inch window cap.

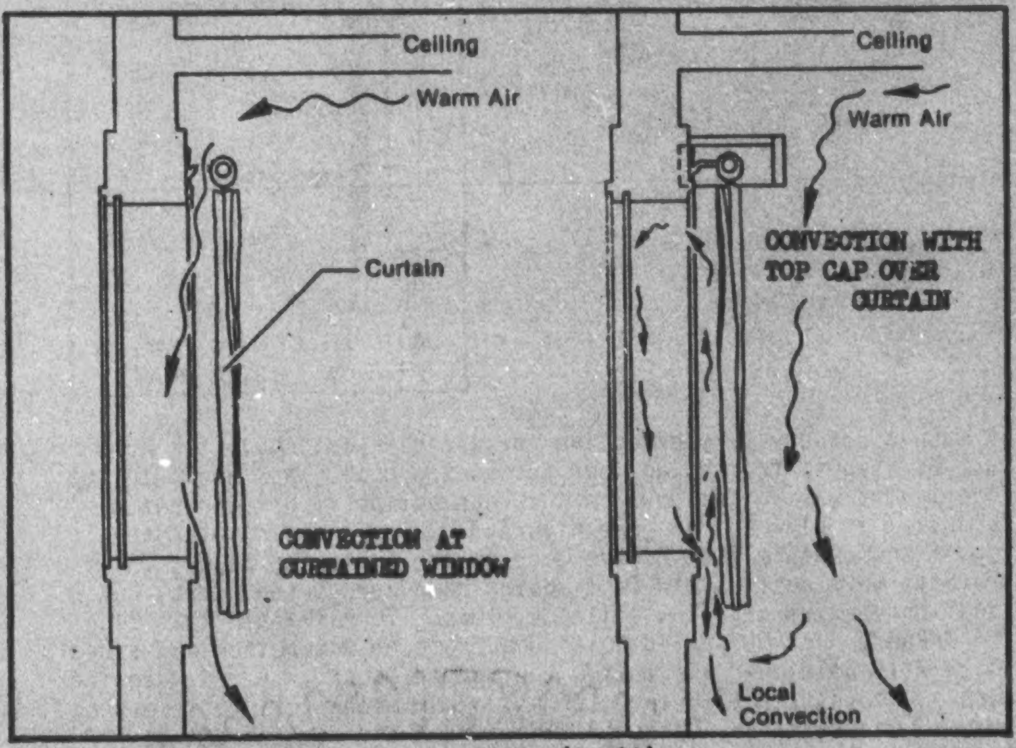

Ceiling
Warm Air
Curtain
CONVECTION AT CURTAINED WINDOW
Ceiling
Warm Air
CONVECTION WITH TOP CAP OVER CURTAIN
Local Convection

Figure 3.53 (Ecclt)

Interior Shutters

Probably the best way to cut heat loss through a window is to fit it with insulated shutters. Shutters can cut heat losses by 75 percent whenever they're closed. An insulated shutter is simply a panel made of an insulating material covered with a protective covering. At present, there are very few manufacturers that makes such shutters, so the imagination and the skill of the homeowner can determine the style, material and size. They needn't look ugly or utilitarian if careful planning goes into design and decorating. (See Figure 3.54).

There are a variety of insulating materials available for the core of the shutters. The most common is one inch rigid board polystyrene (styrofoam) or ureathane foam. These types of insulates can be framed with one inch pine to strengthen the shutters and provide secure anchorage for hinges if preferred. The frames material is then covered with a decorative and fire resistant coating. The fire resistant material is necessary only when fire hazard insulator are used such as rigid board plastics. A trowel on compound called "Dryvit" can be used although it will add weight and cost to the panels. Fire-retardant wall coverings, such as vicrtique and flexi-wall could be used as well as foil wall paper or fire-retardant paint.

You can keep the finishing of the shutters simple by painting them to match the walls. They'll look even better if they're dressed up with materials which match the curtains. Upholstery to match or complement a dominant piece of furniture, naps or inexpensive prints refinished paneling could also be used for the covering.

The type and sytle of shutter depends upon the homeowner, but the size is limited by the dimensions of the windows to be covered for small windows one shutter can be used. This type can be installed by attaching it to the window frame with hooks, velcro-tape, friction fit or magnetic clips. (magnetic clips require metal stripping around perimeter of shutter). On the average window, a shutter with just two panels will do the job. In places where the width of a window is too great for a single pair of shutters without creating a serious clearance problem within a room, panels can also be made in multiple accordion fashion (Figure 3.54). By applying hinges alternately on the inside and outside of the panels, the multiple shutter will fold aside easily. Compression type weatherstripping applied to the sides of each joint will insure a good seal. This multiple shutter should also be latched top and bottom at each joint.

Unlike a thermal curtain which is entirely dependent on good window caulking and weatherstripping to be effective, this type of shutter makes an additional barrier to air infiltration. For this reason, and to stop the seepage of warm house air between the panel and window, it's important to latch these shutters firmly closed.

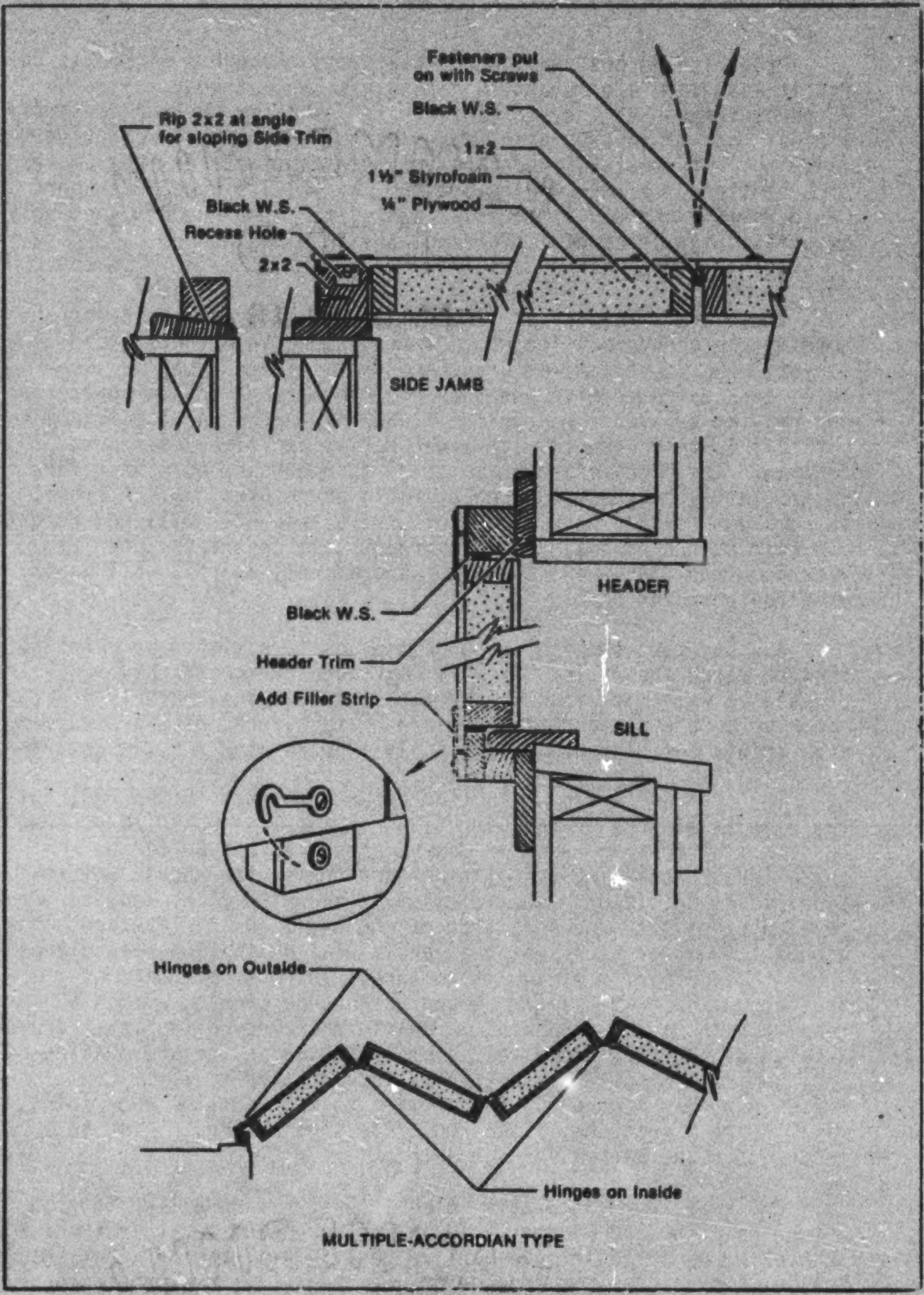
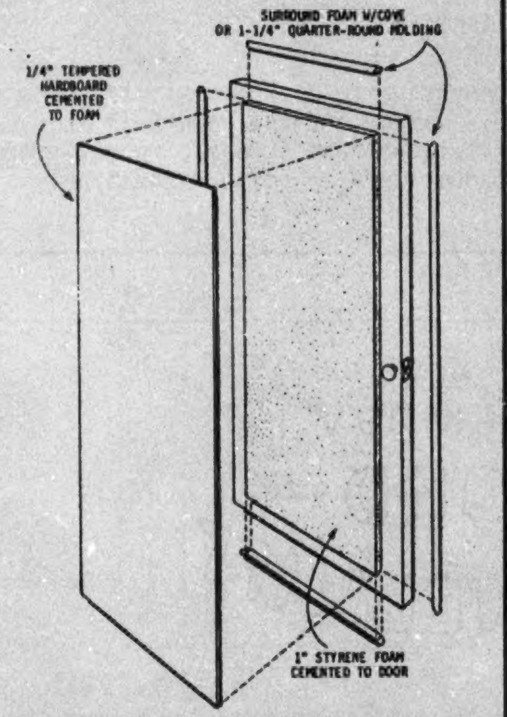

Fasteners put on with Screws
Black W.S.
1x2
1½" Styrofoam
¼" Plywood
Rip 2x2 at angle for sloping Side Trim
Black W.S.
Recess Hole
2x2
SIDE JAMB
HEADER
Black W.S.
Header Trim
Add Filler Strip
SILL
Hinges on Outside
Hinges on Inside
MULTIPLE-ACCORDIAN TYPE

Figure 3.54 (Eccl1)

A local hardware store will carry most types of fasteners to suit such needs. Avoid the straight hook-and-eye type, for these are too loose and won't maintain the compression seal. However, the flat-type hook fasteners do quite well. Whatever fastener is used, be sure that it will maintain a firmer pressure on the weatherstripping.

Storm Doors

Next to windows, doors are the worst sources of heat loss in an otherwise well-insulated house. The average solid wood door has an R-value of around 2. Compare that to the R-value of a typical insulated frame wall (about 13) and it can be seen that doors lose about seven times as much heat per square foot as insulated walls. These figures do not take infiltration around the door into account so doors are even worse. Weatherstripping can cut down on the infiltration problem, but if lower heat losses are excepted through doorways, the doors need to be modified.


SURROUND FOAM W/COVE
OR 1-1/4" QUARTER-ROUND MOLDING
1/4" TEMPERED HARDBOARD CEMENTED TO FOAM
1" STYRENE FOAM CEMENTED TO DOOR

Styrene-foam insulation cemented to the exterior surface of a door can raise the R-value of the door from two to about seven. Use special foam cements; other types will melt the foam. Surround the foam with a cove or quarter-round molding and cover with hardboard. This protects the foam and creates a raised-panel effect.

Figure 3.55 (Hand)

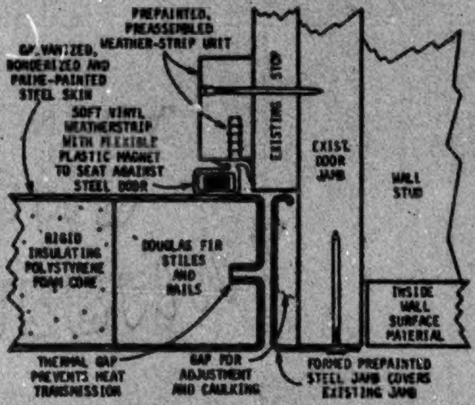
Storm doors are one solution. A wood storm door with a glass area of about 50 percent will use the R-value to about 3.7. Not too good, but it is an improvement. Another good idea is to insulate the exterior door. This can be done fairly simply with one inch foam plastic. The simplest route is to cover just the center part of the door, keeping the insulation inside the doorknob and other hardware, and stopping it short of the edge of the door. This way the additional thickness of the insulation won't interfere with hardware and operation of the door. (See Figure 3.55).

Foam insulation can be cemented to the door, then covered with hardboard for better durability and appearance. NOTE: If foam is used on the inside of the door make sure it is covered with a layer of fire-resistant gypsum board or other material. Plastic foams such as polystyrene and urethane are extremely toxic and flammable. Run molding around the edges of the insulation and the door will have an attractive raised panel effect. A single sheet of foam in the one inch thickness will raise the R-value of the door to around 7 or so. For best effectiveness, put the foam on the outside of the door.

Foam-Core Steel Door

Many times retrofitting doesn't quite do the job. If the work is poorly done, time and money is wasted and the result is an unsightly looking door that still loses heat. Replacing exterior wood doors with foam core steel doors are becoming increasingly

Figure 3.56 (Hand)


PREPAINTED, PREASSEMBLED WEATHER-STRIP UNIT
GALVANIZED, BONDERIZED AND PRIME-PAINTED STEEL SKIN
SOFT VINYL WEATHERSTRIP WITH FLEXIBLE PLASTIC MAGNET TO SEAT AGAINST STEEL DOOR
EXISTING STOP
EXIST. DOOR JAMB
WALL STUD
RIGID INSULATING POLYSTYRENE FOAM CORE
DOUGLAS FIR STILES AND RAILS
INSIDE WALL SURFACE MATERIAL
THERMAL GAP PREVENTS HEAT TRANSMISSION
GAP FOR ADJUSTMENT AND CAULKING
FORMED PREPAINTED STEEL JAMB COVERS EXISTING JAMB

This section of a foam-core Ever/Strait steel door shows the thermal break in steel skin and installation details. This is a door specifically designed for easy installation in remodeling situations. It's slightly undersize to fit into the old opening. Note the freezer-type magnetic weatherstripping.

popular. Early foam steel doors were not much better energy savers than wood doors because the steel skin was one piece. As a result, the metal skin conducted heat out around the foam insulators. During very long temperatures, it was not uncommon to see frost form on side of the door. New designs have solved that problem by interrupting the steel skin around the edges of the door, forming a thermal break. In addition, steel doors can utilize magnetic weatherstripping of the type used on modern refrigerators and freezers. A flexible magnetic inside a plastic sheave of weatherstripping pulls the weatherstripping tight against the door whenever it is closed to provide an excellent seal against air infiltration. (See Figure 3.56).

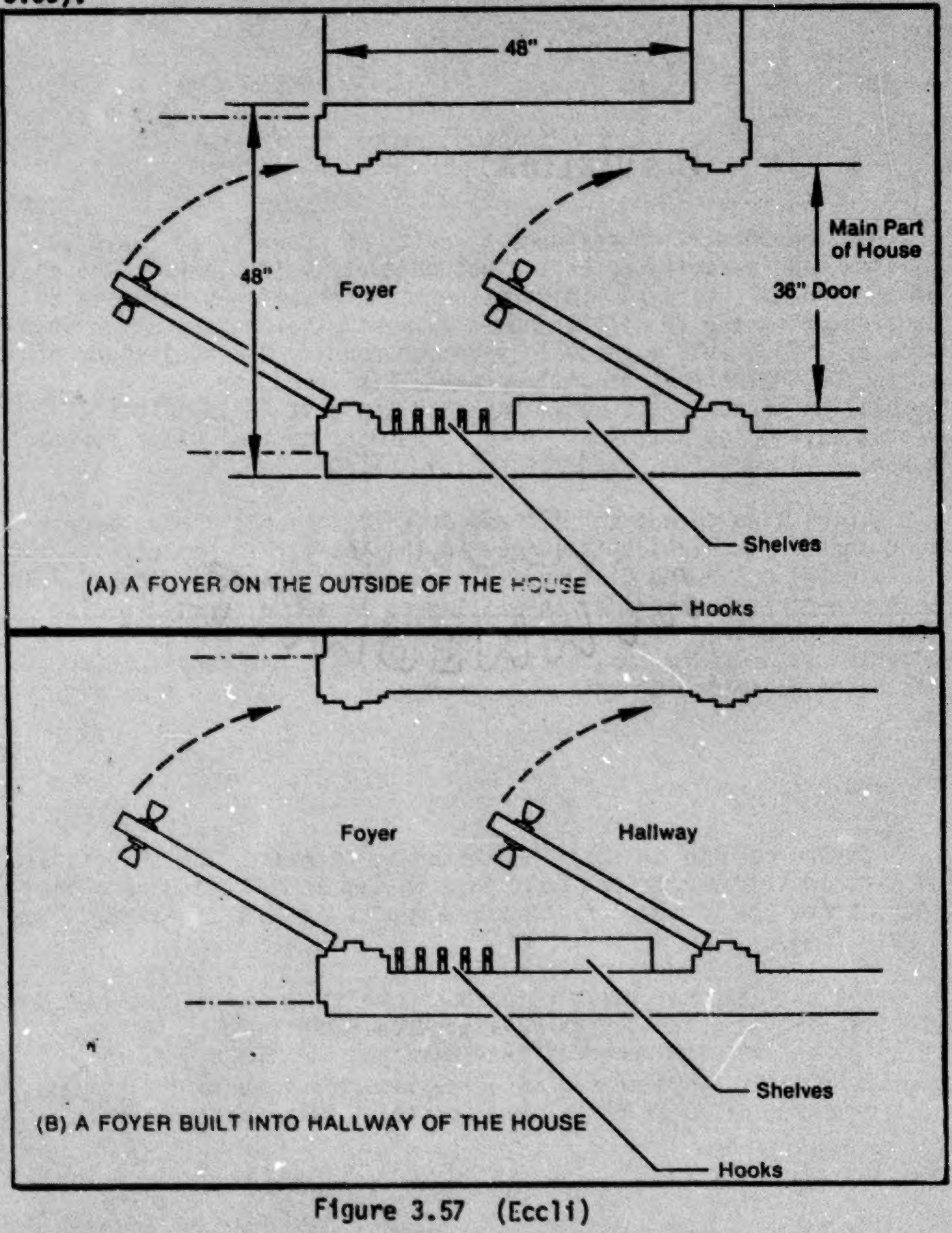

48"
48"
Foyer
Main Part of House
36" Door
Shelves
(A) A FOYER ON THE OUTSIDE OF THE HOUSE
Hooks
Foyer
Hallway
Shelves
(B) A FOYER BUILT INTO HALLWAY OF THE HOUSE
Hooks

Figure 3.57 (Eccli)

Vestibule

Adding storm doors, insulating a door, or installing an energy-efficient door all help out losses while the door is closed, but none of these ideas help at all whenever the door is opened to enter or leave the home. Everytime the door swings open, in comes a blast of cold air. The solution here is an airlock or vestibule-a sort of enclosed porch with its own door. This arrangement keeps in the heat. Even when the outer door is open as one enters or exists, the inner door remains closed. (See Figure 3.57).

SECTION IV

Insulation

Of the 70 million residential units in America, at least 18 million single-family homes are not adequately insulated. One goal of the Federal Energy Administration's conservation program is to "button up" these 18 million homes to meet minimum insulation standards by 1985. This move could save our country the equivalent of up to 350,000 barrels of oil per day. Six inches or more of insulation in the attic could pay back its cost in less than 2 years, saving the homeowner up to 30 percent on fuel bills for each month.

Insulating to add comfort and save dollars has always made good sense. Insulation is unique in the ability to pay off its costs with continuing dividends of lower heating/cooling costs. In this era of fuel shortage, insulating to conserve energy is also good citizenship. As a major factor in continuing energy efficiency, properly applied insulation in all new construction has become a matter of national urgency.

Thermal Insulation

The purpose of thermal insulation is to resist the transmission of heat loss in winter and heat gain in summer by acting as a barrier across one or more of the three routes of heat transfer. (See Figure 3.58).

All building materials have some insulating value, but the term "insulation" is generally associated with light weight, porous, bulky materials with numerous dead air spaces. The degree of insulating efficiency of any material is determined mainly by the number of air cells it contains. In almost all cases, thermal

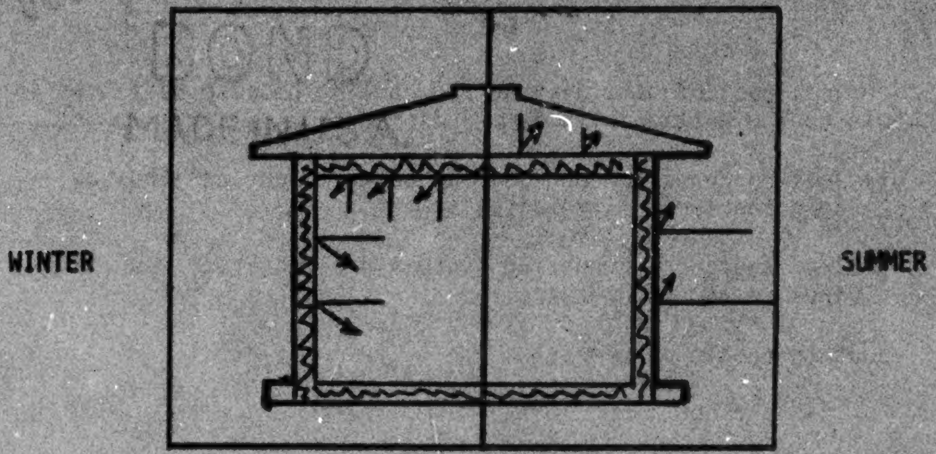

WINTER
SUMMER

Figure 3.58

resistance of an insulating material is in direct proportion to the number of its cells. Exceptions to this are materials such as aluminum foil which insulate by reflecting radiant heat. The individual minute air cells, because of their size, do not permit transfer of heat through convection since the air space is to small to permit air movement. Air cells transfer heat by radiation since some of the radiated heat striking a dead-air space is not transmitted to the opposite surface. Little heat is transmitted by conduction because continuity of material is broken by air cells. (See Figure 3.59).

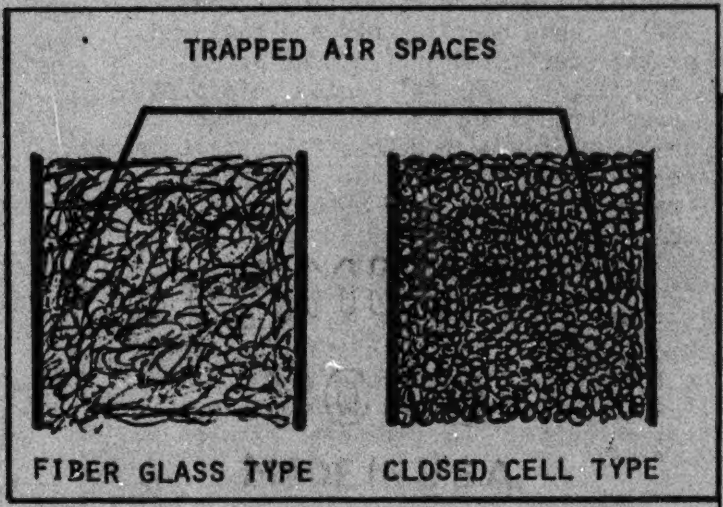
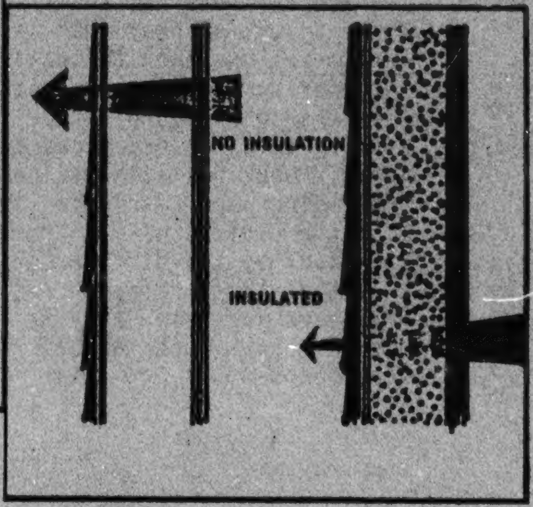

TRAPPED AIR SPACES
FIBER GLASS TYPE
CLOSED CELL TYPE

Figure 3.59 (Eccl1)


NO INSULATION
INSULATED

When insulation is properly chosen and correctly installed, it has several beneficial functions:

- -reduces cost of home heating and cooling because heat loss in winter and heat gain in summer is reduced.
- -reduces condensation or sweating on walls and ceilings by keeping the surfaces relatively warm.
- -smaller heating and cooling systems are required, resulting in savings on equipment costs.
- -adds to resale of home.

Effectiveness

The effectiveness of thermal insulation is indicated in a variety of ways. One way is designated as "U" value. "U" value is overall heat transmission coefficient expressed in BTU's that will pass through a combination of materials and air spaces such as the construction of a roof, a ceiling, a floor or a sidewall of a building in a given time. This heat loss or "U" factor is computed on the basis of each degree difference in opposing temperatures per sq. ft. per hour. The smaller the "U" factor the better the insulator.

In order to obtain the "U" factor for part of a building, it is necessary to know the individual conductivity coefficient of each individual building material included in the construction. (See Table 3.C on the following page). These coefficients are designed commonly at the "K" factors or the coefficients of conductance which are referred to as the "C" factor. The "K" factor refers to the amount of heat that will pass through one sq. ft. of homogeneous material one inch thick, in one hour, for each degree Fahrenheit of temperature difference between the two surfaces. The "C" factor refers to any combination of materials that are of such character that it is not practical to use "K" coefficient for appraising their heat-resisting values. Such materials as hollow tile, building paper, shingles or concrete blocks are examples of materials that are difficult to appraise on the basis of a one-inch thickness. Basically, the difference between the "C" factor and the "K" factor is that the "C" factor refers to actual thickness of the material, however variable, and the "K" factor always refers to a one inch thickness. Both factors represent rate of heat transfer between two surfaces.

R factor

The most common method of determining insulation effectiveness is designated by the letter R. "R" factors indicate the resistance of the insulating material to heat transfer under known conditions.

This list is not intended to include all types of building materials, but only materials commonly used in residences. If necessary, select the material most similar, and the resulting values will not substantially affect the calculation.

MATERIAL	THICKNESS (Inches)	R VALUE	U VALUE
Air Film and Spaces:			
Air space, bounded by ordinary materials	3/4 or more	.91	1.10
Air space, bounded by aluminum foil	3/4 or more	2.17	.46
Exterior surface resistance	—	.17	5.88
Interior surface resistance	—	.68	1,47
Masonry:			
Sand and gravel concrete block	8	1.11	.900
	12	1.28	.781
Lightweight concrete block	8	2.00	.50
	12	2.13	.469
Face brick	4	.44	2.27
Concrete cast in place	8	.64	1.56
Building Materials-General:			
Wood sheathing or subfloor	3/4	1.00	1.00
Fiber board insulating sheathing	3/4	2.10	.476
Plywood	5/8	.79	1.26
	1/2	.63	1.58
	3/8	.47	2.12
Bevel-lapped siding	1/2x8	.81	1.23
	3/4x10	1.05	.952
Vertical tongue and groove board	3/4	1.00	1.00
Drop siding	3/4	.94	1.06
Asbestos board	1/4	.13	7.69
3/8" gypsum lath and 3/8" plaster	3/4	.42	2.38
Gypsum board (sheet rock)	3/8	.32	3.12
Interior plywood panel	1/4	.31	3.22
Building paper	----	.06	16.66
Vapor barrier	----	.00	0
Wood shingles	----	.87	1.14
Asphalt shingles	----	.44	2.27
Linoleum	----	.08	12.5
Carpet with fiber pad	----	2.08	.480
Hardwood floor	----	.71	1.40
Insulation Materials (mineral wool, glass wool, wood wool):			
Blanket or batts	1	3.70	.270
	3 1/2	11.00	.090
	6	19.00	.052
Loose fill	1	3.33	.300
Rigid insulation board (sheathing)	3/4	2.10	.476
Windows and Doors:			
Single window	---	approx-1.00	1.00
Double window	---	approx-2.00	.5
Exterior door	---	approx-2.00	.5

Insulation Value of Common Materials

Table 3.C

The larger the "R" factor, the better the resistance to heat resistance to heat transfer, hence the better the material is as an insulation. Materials with a high "R" factor have low heat loss.

"R" is the reciprocal of "C", "U", or "R" (1/C, 1/U, or 1/K), so to obtain "R" value when "U" factor is known simply divide by the "U" factor. Example: "U" = .5, "R" = 1 ÷ .5 = 2. Most manufacturers of insulation have adapted the "R" rating and stamp it on their products for easy evaluation by the consumer. The "R" factors of two or more different materials or of different thickness of the same material may be added directly to determine the total "R" for combination. "C", "U", and "K" values cannot be added until they are converted. Figure 3.60 illustrates how to determine total "R" value of a wall section.

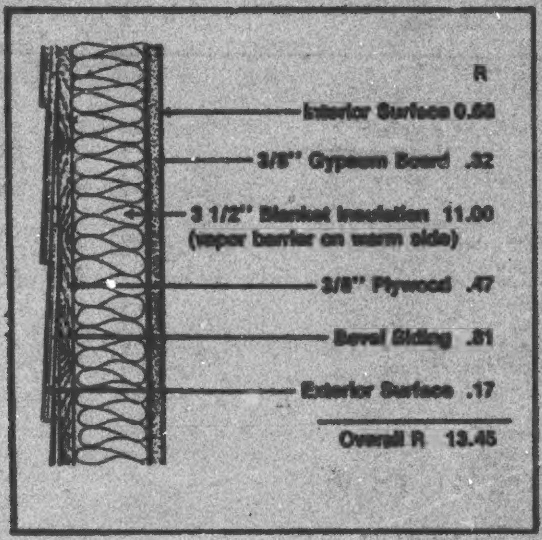


Figure 3.60

Vapor Barriers (See Sector VI of this unit for specific information.)

Many materials used as interior coverings for exposed walls and ceilings, such as plaster, dry wall, wood paneling, and plywood, permit water vapor to pass slowly through them during cold weather. Temperatures of the sheathing or siding on the outside of the wall are often low enough to cause condensation of water vapor within the cavities of a framed wall. When the relative humidity within the house at the surface of an unprotected wall is greater than than within the walls, water vapor will migrate through the plaster or other finish into the stud space; there is will condense if it comes in contact with surfaces colder than its dewpoint temperature.

Proper location of a vapor barrier is an essential factor in the installation of insulation in the home. Vapor barriers restrict the penetration of water vapor into or through insulation where it can condense either in the insulation or on components of the wall framing such as wood studs, sheathing, and siding. This condensation results in wet insulation, rotting wood, weak structural members, and sometimes peeling paint. (See Figure 3.61).

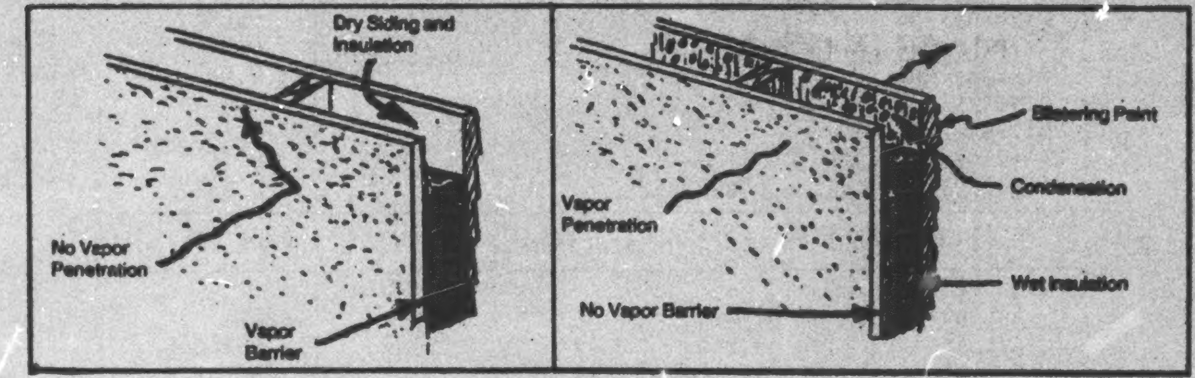


Figure 3.61

The permeability of the surface to such vapor movement is usually expressed in "perms," which are grains (438 grains per ounce) of water vapor passing through a square foot of material per hour, per inch of mercury difference in vapor pressure. A material with a low perm value (1.0 or less) is a barrier, while one with a high perm (greater than 1.0) is a "breather." Table 3.D on the following page lists vapor barriers and their perm rating.

Areas of Vapor Barrier Use

Vapor barriers are used in three general areas of the house to minimize condensation or moisture problem: walls, ceilings, floors. Vapor barriers used on the warm side of all exposed walls, ceilings, and floors greatly reduce movement of water vapor to colded surfaces where harmful condensation can occur. For such uses it is good practice to select materials with perm values of 0.25 or less. Such vapor barriers can be apart of the insulation or a separate film. Commonly used materials are: (a) asphalt coated or laminated papers; (b) Kraft backed aluminum foil; and (c) plastic films such as polyethylene: foil-backed gypsum board and various coatings also serve as vapor barriers. Fair protection may be obtained in existing structures by use of one of these methods: (1) apply two coats of aluminum-in-varnish paint, or two or more coats of a good alkyd base semigloss paint over a primer coat of aluminum paint on walls and ceilings; (2) covering the wall and ceiling with a washable plastic wallpaper.

Table 3.0 Permeance of Vapor Barriers

Material (Plastic and Metal Foils)	Perm rating
Aluminum foil (1 mil)	0.0
Aluminum foil (0.35 mil)	0.05
Polyethylene (2 mil)	0.16
Polyethylene (4 mil)	0.08
Polyethylene (6 mil)	0.06
Polyethylene (8 mil)	0.04
Polyethylene (10 mil)	0.03
Polyester (1 mil)	0.7
Cellulose acetate (10 mil)	0.46
Polyvinylchloride, unplasticized (2 mil)	0.68
Liquid-Applied Coating Materials	**Perm rating**
Paint--2 coats	
Asphalt paint on plywood	0.4
Aluminum varnish on wood	0.3-0.5
Enamels in smooth plaster	0.5-1.5
Primers and sealers on interior insulation board	0.9-2.1
Various primers plus 1 coat flat oil paint on plaster	1.6-3.0
Flat paint on interior insulation board	4
Water emulsion on interior insulation board	30-85
Paint--3 coats	
Exterior paint, white lead and oil on wood siding	0.3-1.0
Exterior paint, white lead-zinc oxide and oil on wood	0.9
Styrene-butadiene latex coating, 2 oz./sq.ft.	11
Polyvinyl acetate latex coating, 4 oz./sq.ft.	5.5
Asphalt cut-back mastic, 1/16 in dry	0.14
3/16 in. dry	0.0

When installing a vapor barrier, it is imperative that it be applied in a continuous matter for maximum efficiency. Any holes punched in the barrier during installation must be patched to resist moisture leakage.

WHERE TO INSULATE

1. EXTERIOR WALLS. Sections sometimes overlooked are the wall between living space and an unheated garage or storage room, dormer walls, and the portion of wall above the ceiling of an adjacent section of a split-level home. Pack insulation in narrow spaces between jambs and framing.
2. CEILINGS WITH COLD SPACES ABOVE DORMER CEILINGS. An attic access panel can be insulated by stapling a piece of mineral wool blanket on its top.
3. KNEE WALLS WHEN ATTIC SPACE IS FINISHED AS LIVING QUARTERS.
4. BETWEEN COLLAR BEAMS, LEAVING OPEN SPACE ABOVE FOR VENTILATION.
5. AROUND THE PERIMETER OF A SLAB ON GRADE.
6. FLOORS ABOVE VENTED CRAWL SPACES. When a crawl space is used as a plenum, insulation is applied to crawl space walls instead of the floor above.
7. FLOORS OVER AN UNHEATED OR OPEN SPACE AS OVER A GARAGE OR A PORCH. The cantilevered portion of a floor.
8. BASEMENT WALLS WHEN BELOW-GRADE SPACE IS FINISHED FOR LIVING PURPOSES.
9. IN BACK OF BAN OR HEADER JOINTS.

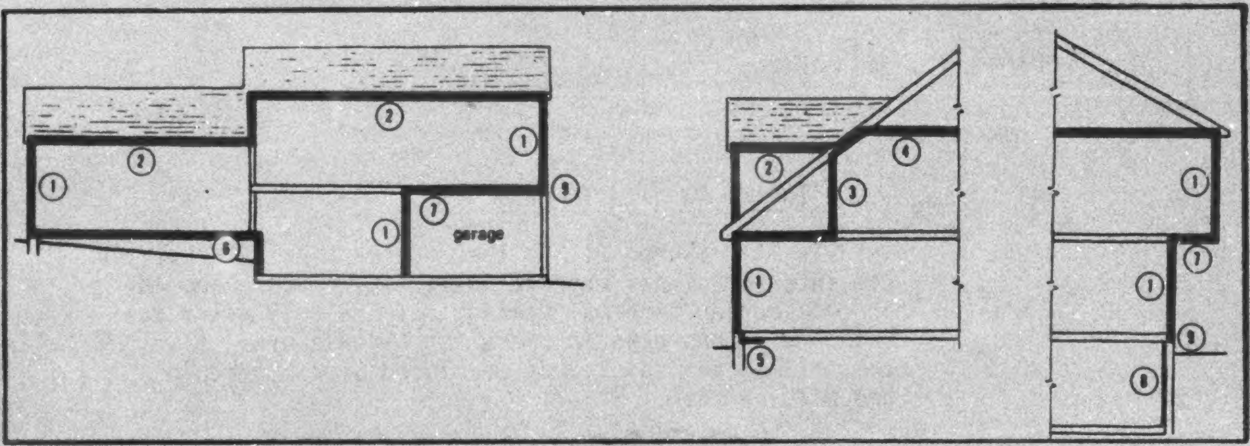


Figure 3.62

Determining Insulation Needs

There are a number of ways one can determine the insulation needs of a home. Inspection is probably the easiest and requires no special expertise or tools. This method is simply examining various areas of the house to see how much insulation is presently installed and compare it to the recommended amount determined by local standards or national insulation firms.

Attics are usually easy to check. If it is open, simply measure if there's insulation there and compare it to recommended minimums. If it's below the minimum insulation should be installed. A closed floor attic may require a floor board to be lifted and then inspected.

Other spots, such as crawl spaces, basements, ceilings over unheated porches or garages are usually easy to check by eye. Finished walls and ceilings are much more difficult. To check these areas, compare the temperature difference of the exposed wall or ceiling to that of an inside partition by touching. If the exterior wall is insulated, it should feel close to the same temperature as the interior partition. If it feels appreciably colder, suspect that it isn't insulated. For a further check, remove an electrical outlet from the exterior wall. If there's a gap around the metal junction box behind the outlet, shine a flashlight through the gap and check for insulation. If there's not enough of a gap, slice away the wallboard a little.

The most accurate method to determine the adequacy of wall insulation in a completed structure is measure the "U" value of a ceiling or wall section. This will indicate the heat loss transmission coefficient of the section. When compared to a wall or ceiling section without insulation the difference will indicate the need for insulation. The following formula can be used to solve for "U" value in a wall section.

Solving for U value

Formula = Ts - Ti - (U x Rx x T)

-Ts = Inside Surface Temperature

Ts is measured with a thermometer taped directly to the interior of air exposed wall. The reading should be made during a normal heating day and only after the thermometer has been in place for a few hours. Also, the thermometer should not be placed over a stud in the wall section.

-Ti = Inside Air Temperature

Ti is found by measuring the temperature inside the home in the same room as the Ts measurement. Ti and Ts measurements should be taken at the same time.

-u = Unknown

-Rx = R value for Inside Air Film (0.68 for wall)

-T = Difference between Inside and Outside Temperature

Example:
$Ts = 60^\circ$
$Ti = 70^\circ$
$Rx = 0.68$
$T = 40^\circ$

$$60^\circ = 70^\circ - (U \times 0.68 \times 40^\circ)$$

Step I - Multiply the values inside the bracket.

$$60^\circ = 70^\circ - 27.2U$$

Step II - The total of bracket value and move to the other side of the formula.

$$27.2U = 70^\circ - 60^\circ$$

Step III - Subtract the degree on the left side of the expression from the side and solve for U.

$$27.2U = 10^\circ$$
$$U = 10^\circ - 27.2$$
$$U = 0.367$$

Step IV - Find R value to determine the total resistance of the wall.

$$R = 1/U$$
$$R = 1/0.367$$
$$R = 2.7$$

The "R" value indicates the total amount of resistance the wall section has to heat loss. A typical wood frame wall section fully insulated (3-1/2 inches) of fiberglass has a "R" value of approximately 14. By this example, it is clear that very little, if any, insulation exists in the wall.

What is Best?

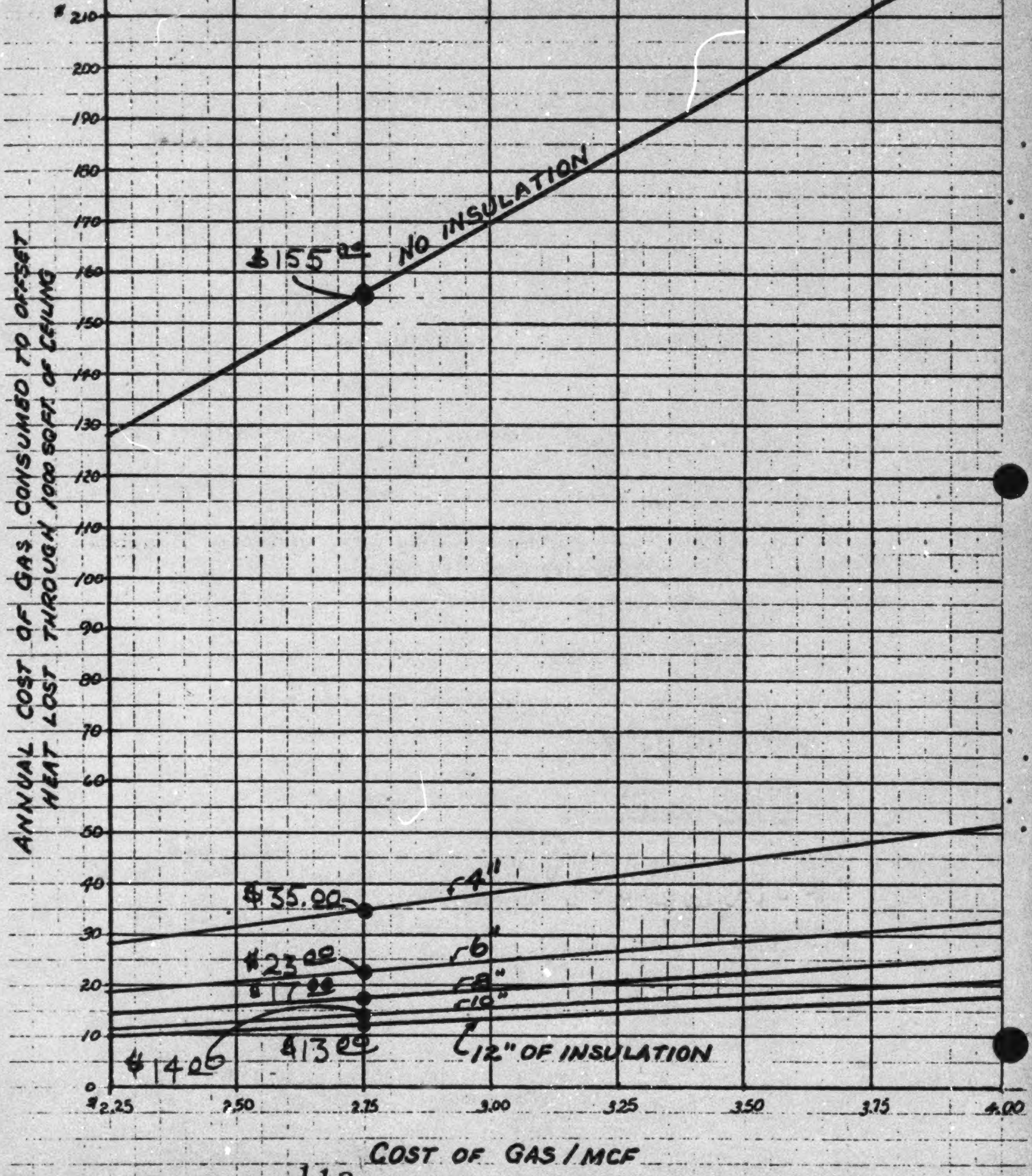
The major reason for installing insulation is to save money on heating and cooling bills. Even though a savings does exist, it is

$$HC = \frac{24\,HR \cdot 5402\,DD \times HL}{1010\,BTU/CUFT \cdot 70° TO \cdot 75\% EFF}$$

75% EFF (SPF) IS ARBITRARY - GAS HEAT IS NORM 65 SPF' HOWEVER THERE ARE USUALLY GAINS FROM THE MNEY WHICH PASSES THROUGH THE AREA STUDIED.

SAVINGS, IE DIFF. BETWEEN INSULATION LEVELS SHOULD REMAIN THE SAME AT EITHER SPF.

COST OF HEAT LOST AT VARIOUS FUEL COSTS.

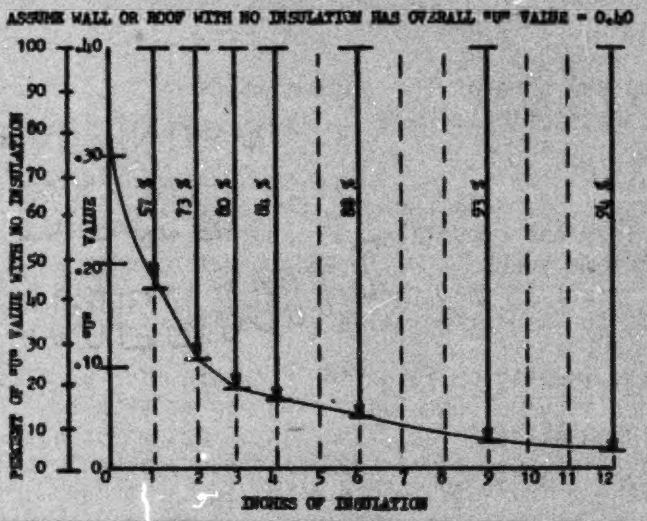


possible to insulate a house to a point where the money spent on insulation far exceeds the money saved on fuel. Graphs 3.I and 3.II on the following pages illustrate the effectiveness of different amounts of insulation.

Several factors determine when the returns begin to diminish: the cost of fuel; climate; the cost of new insulation; and the amount of time one is willing to wait to recover the cost. Still there's some evidence that the optimum amount of insulation is usually somewhere below the widely recommended levels. Figure 3.63 illustrates the recommended insulation standards for ceilings, walls, and floors by Owens-Corning fiberglass. These figures were developed from a comprehensive computer analysis of 71 United States cities. Owens-Corning based the recommendations on new construction, average zone weather data, current and projected electric heating and cooling costs, and a return on investment for 20 years with savings discounts 10% each year.

Graph 3.I

EFFECT OF INSULATION ON "U" VALUE



Assume: Total Heating Bill for one season = $200.00
Wall or roof load = 25% of Total Ht. loss = .25 x $200 = $50
% Difference Between 12" and 4" = 94 - 84 = 10%
Savings per year for extra 8" insulation = .10 x $50 = $5.00/Year
%Difference Between 12" and 6" = 94 - 88 = 6%.
Savings per year for extra 6" insulation = .06 x $50 = $3.00/Year
At either of these figures how many years would it take to save in the heating
bill the cost of an extra 6 or 8 inches of insulation?
The savings per year would not pay the interest on the investment.

The Federal Housing Administration (FHA) recommendations are much less than this. According to the 1973 building standards, the minimum recommendations are R-19 for ceilings; R-11 for floors and R-11 for walls.

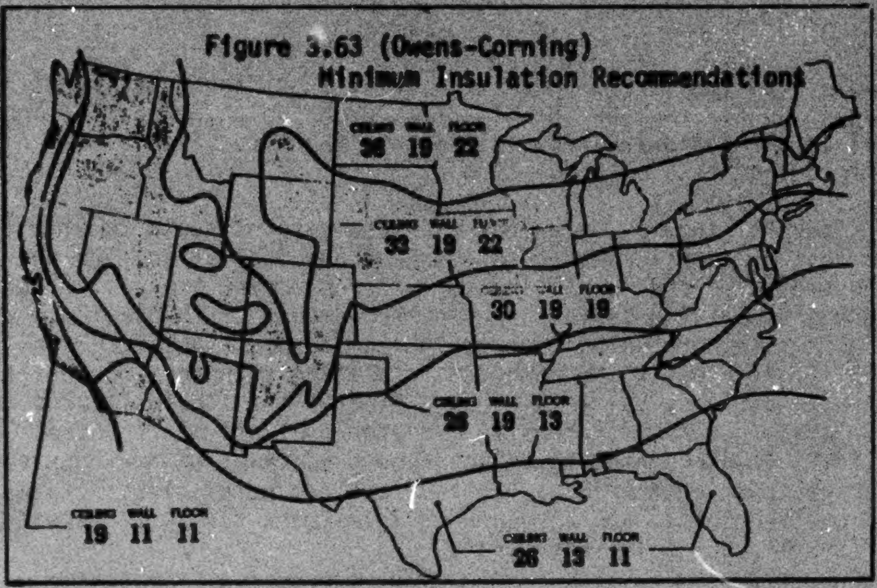


Figure 3.63 (Owens-Corning)
Minimum Insulation Recommendations

KINDS OF INSULATION

Following are some of the various kinds of insulation used in residential construction.

FIBERGLASS

Fiberglass is perhaps the most common of all insulators. It is fire and vermin proof, moderate in cost, and easy to install. However, over some years it will tend to mat down or settle on itself. The result is that the material is compressed a bit and loses some of its insulation value. (See Table 3H)

Fiberglass insulation is a fine flexible mass of glass fibers made by attenualting molten glass. The raw materials of fiberglass are sand, calcium oxide (lime), and sodium oxide (soda). Other ingredients may include lead oxide, saltpeter, arsenic and white oxide. When these ingredients are mixed in the proper proportion and melted in a 15% soda, and 9% lime. The other ingredients mentioned above may make up about 4% of the total mixture. After the ingredients have been mixed properly, they are poured into a furnace fired by natural gas, oil or coal to a temperature of approximately 3200°F. The mixture is heated until molten. The molten glass then flows through tiny orfaces at the base of the furnace by gravity. Some manufacturers pour the molten glass from the furnace through a strainer type of device. This flow action of the molten glass is caught by high pressure jets of air or steam and drawn into fine fibers 8 to 15 inches long at a density of 1.5 lbs/ft. At this density, the glass is thermally resistant up to 1000°F. The drawing action of the jets are very violent which causes shreading of the fibers. The shreaded fibers fall into a conveyor belt driven by an electric motor which transports them to be bonded and cured. The bonding is done by treating the glass fibers with thermosetting

Table 3.8

The following examples will illustrate the reduction in Thermal Resistance (R) values at various compressed thicknesses:

R-19 at 6-½"

Thickness	Thickness Reduction	R Value
6-½"	0	19.0
6"	7.7	17.7
5-½"	15.4	16.8
5"	23.1	15.7
4-½"	30.8	14.6
4"	38.5	13.3
3-½"	46.2	12.2
3"	53.8	10.7
2-½"	61.5	9.4

R-19 at 6"

Thickness	Thickness Reduction	R Value
6"	0	19.0
5-½"	8.3	17.7
5"	16.7	16.6
4-½"	25.0	15.5
4"	33.3	14.3
3-½"	41.7	12.8
3"	50.0	11.4
2-½"	58.3	9.9

R-14 at 5"

Thickness	Thickness Reduction	R Value
5"	0	14.0
4-½"	10.0	13.2
4"	20.0	12.3
3-½"	30.0	11.3
3"	40.0	10.1
2-½"	50.0	8.9

R-14 at 4-½"

Thickness	Thickness Reduction	R Value
4-½"	0	14.0
4"	11.0	13.2
3-½"	22.2	12.2
3"	33.3	10.9
2-½"	44.4	9.5

R-11 at 4"

Thickness	Thickness Reduction	R Value
4"	0	11
3-½"	12.5	10.1
3"	25.0	9.1
2-½"	37.5	8.1

R-11 at 3-½"

Thickness	Thickness Reduction	R Value
3-½"	0	11
3"	14.3	10.0
2-½"	28.6	[illegible]

resin after which it is compressed to the desired density by rollers and cured by passing through a heat chamber. When the glass is rolled to the desired density and cured, it is then transported to be cut, trimmed and packaged. The completed fiberglass insulation ranges in size from 1 to 12 inches thick, 15 to 23 inches wide, and 32 or 56 foot rolls. Batt insulation is produced in 4 foot sections.

MINERAL WOOL OR ROCK WOOL

Rock wool is a thermal and sound insulating material manufactured from a variety of substances such as limestone, lead, slag, iron slag, old firebrick, scrap metals with limestone clay and others. Originally, rock wool was produced from furnace slag which gave it the name of slag wool. Rock wool is commonly referred to as mineral wool. In general, the most common method of wool production is to melt the slag in a cupola until a low viscosity is reached and then pouring a fine stream of this material into a stream of air blast. The cupolas used range in size from 4 to 5 feet in diameter and 7 to 8 feet high. They are fired by fossil fuels to temperatures 2300 to 3350F. The molten slag is poured through an orifice opening ranging from 0.075 to 0.84 inc. The steam blast pressures range 45 to 125 lbs/in. while air pressures range from 50 to 95 lbs/in. The blast of steam or air shreds the slag stream into fine particles (3 to 10 microns in diameter), and produces the wool fibers. This wool is blown into collecting rooms, from which it is removed by conveyor. At this point it is weighed and packaged for shipment. Due to the nature of the material fire and vermin retardant are not required.

CELLULOSE FIBER

Cellulose fiber insulation is a recycled type of insulation made from old newspapers, cardboard boxes, and other kinds of waste paper....and treated with chemicals to make them self-extinguishing and vermin proof. The following formulation is a typical example of the materials needed for cellulose insulation.

INGREDIENTS BY WEIGHT		FOR 100 LBS. PAPER
Paper	10 lbs.	100 lbs.
Aluminum Sulfate	3 lbs.	30 lbs.
Borax	1.5 lbs.	15 lbs.

Cellulose fiber is made from newspaper and scrap cardboard which has been collected and brought to the plant. At the plant, the cellulose base paper is stored and thoroughly dried. At the point in which the paper is moisture free, it is loaded upon a conveyor system and transported to a series of shredders and grinders. The shredders and grinders mulch the material into a fluffy fuzzy mass of fibers. To treat the cellulose fiber for fire and rodent resistance, the fiber is treated with borax and aluminum sulfate. These chemicals are mulched directly into the fiber as the newspaper goes through the shredders and grinders. The fluffiness of the material has a tendency to hold the chemicals into the insulation rather than settle out of the fiber. After the cellulose material is completely mulched and mixed with chemicals, it is transported by conveyor to be weighed, separated and packaged. Cellulose fiber insulation is usually packaged in 80 lb. bags and can be installed by pouring or blowing it into walls and attics of houses. Cellulose with the federal specifications number HH-I-515C is the only cellulose that is approved by the government for home use.

PLASTIC INSULATION

The most common type of plastic insulation is polystyrene, which comes either as a blue "closed-cell" foam board or as white granule boards where granules have been heat and pressure treated so they adhere together. Expanded polystyrene is commonly known as beadboard and extruded polystyrene is known as styrofoam. These materials form their own vapor barriers. The resistance of these materials is about 5.5 for the blue closed-cell type and 4.0 for the white granule type. Polyurethane, on the other hand, comes as closed-cell foam boards or can be professionally blown into place inside walls, ceilings, or floors as a foam (not recommended). In either case, its resistance value is about 6.5 per inch. Polystyrene and polyurethane tend to be expensive. Moreover, while both are good insulators and do not attract moisture or vermin, there are extreme fire hazards involved. Both will burn very rapidly and give off toxic gases, particulary when placed in a vertical position. These materials should, therefore, never be installed where they will be exposed. The best applications are for perimeter insulation on the outside of foundation walls.

UREA-FORMALDEHYDE FOAMED IN PLACE INSULATION

Urea-formaldehyde foam is a two part insulation system made of liquid urea-formaldehyde resin plus a hardener containing a foaming agent. It is non-flammable and does not settle, but it shrinks somewhat and occasionally releases an odor when first applied, so it is better to install during warm weather when windows can be kept open. While more expensive than blown-in loose-fill, it is an excellent insulation material. When foamed in place, it will completely fill the stud space as it solidifies and it will not settle like loose-fill insulations. The resistance is about 4.8 per inch of thickness.

TYPES OF INSULATION

Thermal insulation is produced in several common forms from a wide variety of materials. Those types most used in residential construction are batt and blanket, loose-fill form, rigid panel and formed in place.

BATT AND BLANKET FORM

Materials:	Glass fiber or mineral wool formed into: Batts-insulation pieces 4' or 8' long, or Blankets-may be purchased in rolls over 100 feet long. (Depends on thickness). Both forms usually include a vapor barrier of Kraft/asphalt coated paper or aluminum foil. Batts and blanket are also available without a vapor barrier.
Width:	15 or 23 inches for standard 16 and 24 inch framing spaces.
Thickness:	1 to 12 inches.
R-value:	Batts and blankets are labeled with a R-value for each thickness. (See Table 3I on the following page). R-values on un-faced fiberglass and mineral wool is indicated by strips on the insulation.

"R"	Thickness of Insulation	Number of Strips
R-11	3" - 3-1/2"	111
R-13	3-1/2"	1111
R-19	6" - 6-1/2"	11111
R-22	6-1/2"	111111
R-30	8-1/2 - 9"	None
R-38	12"	None

Use: Batts and blanket insulations are primarily used in new frame construction placed in ceilings, walls and floors. These forms are also very popular in retrofitting floors and walls.

Table 3.I

TYPICAL R VALUES OF VARIOUS INSULATION TYPES							
	R/Inch	Inches Needed for					
		R11	R19	R22	R34	R38	R49
Loose Fill **Blown Machine**							
Fiberglass	R2.25	5	8.5	10	15.5	17	22
Mineral Wool	R3.125	3.5	6	7	11	12.5	16
Cellulose	R3.7	3	5.5	6	9.5	10.5	13.5
Loose Fill **Poured-Hand**							
Cellulose	R3.7	3	5.5	6	9.5	10.5	13.5
Mineral Wool	R3.125	3.5	6	7	11	12.5	16
Fiberglass	R2.25	5	8.5	10	15.5	17	22
Vermiculite	R2.1	5.5	9	10.5	16.5	18	23.5
Batts or Blankets							
Fiberglass	R3.14	3.5	6	7	11	12.5	16
Mineral Wool	R3.14	3.5	6	7	11	12.5	16
Rigid Board							
Polystyrene beadboard	R3.6	3	5.5	6.5	9.5	10.5	14
Extruded polystyrene (styrofoam)	R4-5.41	3-2	5-3.5	5.5-4	8.5-6.5	9.5-7	12.5-9
Urethane	R6.2	2	3	3.5	5.5	6.5	8
Fiberglass	R4.0	3	5	5.5	8.5	9.5	12.5
Foam							
Ureaformaldehyde	R4.8 (35 F)	2.5	4	4.5	7	8	10.5

LOOSE-FILL FORM

Materials: Loose-fill insulations are made from cellulose fiber (shredded paper), glass fiber, mineral wool, vermiculite, perlite, and granulated cork. Loose-fill insulation is packaged in bags or bales in a variety of different sizes.

R-Value: Depends on the various materials, density and installation application.
Approximate values:

Cellulose fiber: R-3.7 per inch thickness
Mineral Wool: R-3.0 per inch thickness
Glass Fiber: R-2.2 per inch thickness
Vermiculite: R-21 per inch thickness

Coverage:

Coverage Chart Per Bag (Cellulose 25 lb.)

Blown-In

	Min. Thickness Installed Insulation Should Not be Less Than	Max. Net Coverage Sq. ft.	Min. Number of Bags Per 1000 ft.	Min. lbs. Per Sq. ft.
Attic*				
50	13.5"	11	91	2.27
40	10.5"	14	71	1.82
32	8.5"	19	53	1.33
24	6.5"	24	42	1.05
22	6.0"	26	38	.96
19	5.0"	31	32	.80
13	3.5"	44	23	.57
11	3.0"	53	19	.47
Sidewalls				
20 (2" x 6" x 16)	5.5"	20	50	1.48
13 (2" x 4" x 16)	3.5"	31	32	.94

*Attic based on 2" x 6" x 16" centers, and 2" x 6" on 24" center, multiply coverage by .96 for 2" x 4" on 24" center, multiply coverage by .94. Sidewall coverage based on studs on 16" centers. For 24" centers, multiply coverage by .96.

Coverage Chart Per Bag (Rock/Mineral Wool 25 lb.)

Blown-In

R	Min. Thickness	Max. Net Coverage Sq. ft.	Min. Number of Bags Per 1000 ft.	Min. Number lbs. Per Sq. ft.
11	33/4"	48 sq. ft.	21	0.63 lb.
19	6-1/2"	28 sq. ft.	36	1.07 lbs.
22	7-1/2"	24 sq. ft.	42	1.25 lbs.
30	10-1/4"	18 sq. ft.	56	1.66 lbs.
38	13"	14 sq. ft.	72	2.15 lbs.

Use: Loose-fill insulation is well adapted for use in walls and ceilings of existing buildings, ceilings of new buildings, and for filling the cores of masonary blocks. Loose-fill insulation is especially good for filling irregular spaces. When used for attic insulation, it will cover ceiling supports and provide more uniform insulation then batts or blankets. When used inside walls, settling out can be a problem, therefore, batt or blanket insulation is recommended for new construction. Loose-fill insulation can be blown or poured. Blown insulation is usually applied to: unfinished attic floors, finished attic floors, finished frame walls and underside of finished floors. Poured insulation is commonly applied to unfinished attic floor and concrete block.

RIGID PANEL FORM

Materials: Rigid board insulation is made of fiberglass or plastic. (polystyrene and polyurethane or other materials such as plant fibers).

Panel Sizes: 2' x 8'; 4' x 8'

Thickness: 1/2 inch to 4 inches

R Value: Varies with material and density.

Expanded Polystyrene (Beadboard) - 3.5 to 4.0 per inch
Extruded Polystyrene (Styrofoam) - 4 to 5.5 per inch
Urethane - 6.2 per inch
Fiber boards - 2.0 - 4.0 per inch

Use: Foamed plastic are commonly used for insulating masonry walls and perimeter of concrete floor slabs. They are particularly suitable for basement wall insulation. When used inside a shelter, plastic insulators must be covered with drywall or paneling for fire safety. Fiber type insulating board can be used as sheathing under house siding.

NOTE: Polystyrene and urethane rigid board insulation should only be installed with 1/2" NON-FLAMMABLE MATERIAL to insure safety.

FOAM-IN-PLACE INSULATION

Material: Urea-Formaldehyde (U-F) is the only suitable kind of foam-in-place material for home insulation. It is non-flammable (if mixed properly) and does not settle, but it shrinks somewhat and occasionally releases an odor while curing. To reduce shrinkage and odor it is recommended that U-F foam should be installed in a wall cavity from 23 to 86 degrees F. Urethane foam is not suitable.

R-Value: 4.8 per inch of thickness.

Use: U-F foam is only to be used in sidewalls of homes. It is especially useful in retrofitting a home. U-F foam is retrofitting a home. U-F foam is NEVER USED IN CEILINGS due to excessive shrinkage and odor.

GOVERMENT LEGISLATION

As of August 23, 1979 the U.S. government has ordered the home insulation industry Thursday to tell consumers exactly how much heat or cold protection they will be buying in products on which they will spend billions in coming years.

The new rules will enable buyers to compare the relative effectiveness of different types of insulation - loose fill vs. blanket type, for instance - since all products must be rated on the basis of the same test.

A Federal Trade Commission investigation that prompted the rule indicated that insulation's price or thickness - indicators on which consumers have traditionally relied - "are not valid yardsticks" for comparison.

As a result, the new rule - effective in late November - will require all types of insulation to be rated by its "R-value," a measurement indicating resistance to heat flow. Products with higher R-values are more effective at keeping out cold or heat.

The rules do not require sellers to tell consumers how many inches of insulation they should buy. Since those requirements vary by geographic area, home owners are advised to check with state and local energy offices or utility companies for that information.

Besides requiring manufacturers to test their products by a standard means to determine the R-value, packages must be labeled with the information.

INSULATION ECONOMICS

How much insulation should my home have? Where should it go? How much does it cost? What are the savings? Can I afford it?

These questions can be answered by a simplified economic analysis -- once you have the facts. The data presented will enable you to make your own financial analysis, and serve as a guide to making the best investment in insulation to save energy and money.

A word about financial analysis -- sounds complicated -- but to simplify it, we'll operate on this premise: that money invested in insulation should earn at least as much as you can get by investing in stocks, bonds, or savings institutions. If insulation will not earn at this rate, it is not a good investment.

Also, if insulation will provide a return greater than you can earn by investing, it will generally pay to borrow money to make the installation now.

We have assumed that you can get a "rate of return" on your investments of about 8%.

The financial analyses we will make are:

I. Payback Period. How many years will it take for the savings to earn back the amount of money you must invest in this project?

Example: If you must invest $1,000 to get a savings of $250 per year, the payback period is 4 years.

$$\text{PP (Payback Period)} = \frac{FC}{S}\ \frac{\text{(First Cost)}}{\text{(Savings)}} \text{ in years}$$

$$PP = \frac{\$1,000}{\$250} = 4 \text{ years}$$

If the payback period is less than half the estimated life of the project, the investment is generally a good one.

The life of insulation is usually regarded as the life of the building, provided the insulation remains intact.

We will use a 20 year estimated life for insulation and double glazing in our analysis.

II. Return on Investment. This concept is superior to the payback period analysis, since it includes depreciation of the investment over its life. While accountants have many ways of looking at depreciation, we'll use the straight line value to keep things simple.

Your $1,000 investment has a life of 20 years. Annual depreciation is 1/20th of the total each year, calculated as follows:

$$\text{DC (Depreciation Charge)} = \frac{FC}{EL}\ \frac{\text{(First Cost)}}{\text{(Estimated Life)}}$$

$$DC = \frac{\$1,000}{20} = \$50 \text{ per year}$$

Return on investment is expressed in percent and is calculated using this formula:

$$\text{ROI\% (Return on Investment in \%)} = \frac{\text{Net Annual Savings - Depreciation Charge}}{\text{First Cost}} \times 100\%$$

In our example:

$$\text{ROI\%} = \frac{\$250 - \$50}{\$1,000} \times 100\% = \underline{20\%} \text{ Return}$$

Since 20% is far better than the current interest rate on borrowed money, and most investment opportunities, this investment appears to be a good one.

III. Calculate the present value of the investment and the benefit cost ratio. This method is presented for those who wish to dig a little deeper.

Dollar invested today in anticipation of a series of future savings over the years have a present value (PV). This concept recognizes that a dollar of savings returned several years later is not as useful as a dollar of savings returned sooner, and later year dollar returns are discounted.

The Present Value is calculated using a factor called the "present worth" factor.

Twenty years of savings at an annual rate of $250 would provide a total of $5,000.

Calculating the present value using the discount factor provides a total far lower:

$$PV = \text{Present Worth Factor (8\% + 20 Yr)} \times \text{Annual Savings} =$$

$$9.818 \times \$250 = \$2,454$$

The Benefit Cost Ratio is the ratio of the Present Value to the First Cost of the Investment.

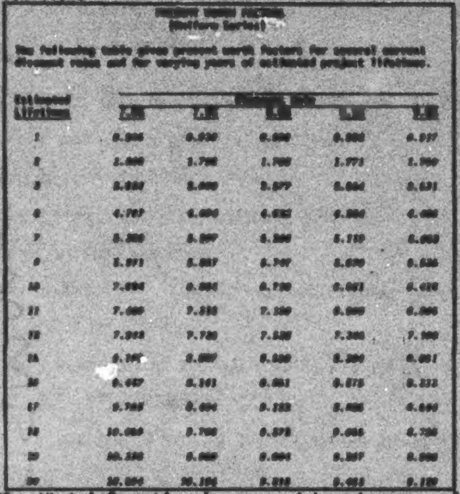
$$B/C = \frac{PV}{FC}\ \frac{\text{(Present Value)}}{\text{(First Cost)}}$$

In our example:

$$B/C = \frac{\$2,454}{\$1,000} = 2.454$$

Benefit Cost Ratios greater than 1 are profitable. A ratio of 1.5 would be more profitable than a 1.25 ratio.

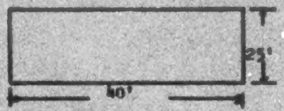
If you have several possible energy saving applications, a comparison of B/C Ratios will indicate the better investment opportunities.



CALCULATIONS. What information do you need to make your calculations? First -- you need to measure your home:

1. Measure the outside length, width, and height.
2. Compute the areas to which insulation may be applied.
3. Count the number of average windows and doors.

We'll use a typical 1,000 square foot home as our example:



A - Attic and Floor Area = L X W = 40' X 25' = 1,000 Sq. Ft.

B - Gross Wall Area = Perimeter X Height (Floor to Ceiling)
= 2 [L + W] X H
= 2 [40'+25'] X 8'

C - Count number of average windows (2.5'X4') and doors (6.8'X3').
We'll assume 11 windows and three doors for this size home.

Window Area = 11 [L X W]
= 11 [2.5' X 4'] = 110 sq. ft.

Door Area = 3 [L X W]
= 3 [6.8' X 3'] = 61.2 sq. ft.

D - Net Wall Area = gross wall area - window area - door area
= 1040 - 110 61.2 = 868.8 sq. ft.

Approximate installed prices for insulation per square foot are:

Location	Amount	Open	With Floor in Place		
ATTIC	4"	39¢	40¢		Cellulose
	6"	51¢	60¢		
	10"	71¢	96¢		
WALL*		Brick	Aluminum Siding	Wood	
	2"	72¢	72¢	60¢	Cellulose
	4"	$1.02	$1.02	$1.02	
FLOOR	4"	39¢	Fiberglass		
	6"	51¢			

Storm Windows - Average Quality and Size = $60 each
Storm Doors - Foam Core (6'8"X3'0") = $275.00 each

*Caution - Applies only to walls having voids or air spaces which can be insulated by blowing the air space full of insulation.

Our example house has an open attic -- brick walls with an air space, 11 windows and 3 doors.

"U" AND "R" VALUES WITH NO INSULATION

WALLS	U	R
3/8" Gypsum Board	3.12	.32
3-1/2" Air Space	1.10	.91
5/8" Plywood	1.26	.78
4" Face Brick	2.27	.44
Exterior Surface Resistance	5.88	.17
Interior Surface Resistance	1.47	.63
TOTAL WALLS	.304	3.28

DOORS		
Exterior	.5	2.00
TOTAL DOORS	.5	2.00

ATTIC (Vented)		
3/8" Gypsum Board	3.12	.32
Exterior Surface Resistance	5.88	.17
Interior Surface Resistance	1.47	.68
TOTAL ATTIC	.854	1.17

WINDOWS		
Single Pane Double Hung	1.00	1.00
TOTAL WINDOWS	1.00	1.00

FLOORS		
Inside Surface	1.47	.68
Inside Surface	1.47	.68
1/2" Plywood	1.59	.63
TOTAL FLOORS	.370	2.70

HEAT LOSS PER SQUARE FOOT

= Heat Loss (U Value) X 70°F (Design Temperature Difference)

Walls = .304 X 70°F = 21.28 BTU/HR/sq.ft.

Attic = .854 X 70°F = 59.82 BTU/HR/sq.ft.

Floor = .370 X 70°F = 25.9 BTU/HR/sq.ft.

Windows = 1.00 X 70°F = 70 BTU/HR/sq.ft.

Doors = .500 X 70°F = 35 BTU/HR/sq.ft.

TOTAL WALL HEAT LOSS PER HOUR

Heat Loss X Net Area = 21.28 X 868.8 = 18,488 BTU/HR

TOTAL ATTIC HEAT LOSS PER HOUR

Heat Loss X Area = 59.82 X 1,000 = 59,820 BTU/HR

TOTAL FLOOR HEAT LOSS PER HOUR

Heat Loss X Area = 25.9 X 1,000 = 25,900 BTU/HR

TOTAL WINDOW HEAT LOSS PER HOUR

Heat Loss X Area = 70 X 110 = 7,700 BTU/HR

TOTAL DOOR HEAT LOSS PER HOUR

Heat Loss X Area = 35 X 61.2 - 2,142 BTU/HR

TOTAL HEAT LOSS PER HOUR OF HOME WITHOUT INSULATION AND STORM WINDOWS/DOORS

Walls	= 18,488 BTUS/HR
Attic	= 59,820 BTUS/HR
Floors	= 25,900 BTUS/HR
Windows	= 7,700 BTUS/HR
Doors	= 2,142 BTUS/HR
Total	114,050 BTUS/HR

SEASONAL HEAT LOSS IN BTUS* (Figured for Fairmont, WV)

$$H = \frac{24hd(t_i - t_a)}{t_i - t_o}$$

$$H = \frac{24 \text{ X } 114,050 \text{ X } 246(70 - 44.5)}{70 - 7}$$

H = 272,550,000 BTUS per heating season

UNITS OF FUEL USED PER YEAR*

Natural Gas @ 75% efficiency = 362,473 cubic feet
#1 Heating Oil @ 75% efficiency = 2672 gallons
#2 Heating Oil @ 75% efficiency = 2595 gallons
Bottle Gas Propane @ 75% efficiency = 3907 gallons
Electric Heat @ 100% efficiency = 79,879 KW

ANNUAL COST OF FUELS WITHOUT INSULATION AND STORM DOORS/WINDOWS

Natural Gas @ $3.00/MCF = $1,087.20
#1 Heating Oil @ .592/gallon = $1,581.82
#2 Heating Oil @ .66/gallon = $1,712.70
Bottle Gas Propane @ .558/gallon = $2,134.35
Electric @ .05/KWH = $3,993.95

INSULATED HOME

If this house is equipped with 6" of fiberglass insulation ("R" 22) in the attic, 3-1/2" of cellulose in the walls ("R" 13), 3-1/2" in the floor ("R" 11), and is equipped with storm windows and doors, the annual heat loss and annual billing on the same rate is estimated as illustrated below:

"U"/"R" Values and Heat Loss with Insulation

- Wall "U" value with 3-1/2" of cellulose fiber = .061
  "R" value = 16.39
  Heat loss of wall with 3-1/2" of cellulose = 4.27 BTU/HR/
- Attic "U" value with 6" of fiberglass = .043
  "R" value = 23.17
  Heat loss of attic with 6" of fiberglass = 3.01 BTU/HR/sq.ft.
- Floor "U" value with 3-1/2" of fiberglass = .073
  "R" value = 13.70
  Heat loss of floor with 3-1/2" of fiberglass = 5.11 BTU/HR/sq.ft.
- Window "U" value with storm windows (2 panes) = .5
  "R" value = 2.00
  Heat loss of windows with 2 panes = 35 BTU/HR/sq.ft.
- Door "U" value with foam core = 1.38
  "R" value = 13.70
  Heat loss of door with foam core = 9.65

---

* See Unit 2, Heat Transfer "Predicting Future Need" for specific formula procedure.

TOTAL WALL HEAT LOSS WITH INSULATION

Heat loss X area = 4.27 X 868.8 = 3,709 BTU/HR

TOTAL ATTIC HEAT LOSS WITH INSULATION

Heat loss X area = 3.01 X 1,000 = 3,010 BTU/HR

TOTAL FLOOR HEAT LOSS WITH INSULATION

Heat loss X area = 5.11 X 1,000 = 5,110 BTU/HR

TOTAL WINDOW HEAT LOSS WITH 2 GLASS PANES

Heat loss X area = 35 X 110 = 3,850 BTU/HR

TOTAL DOOR HEAT LOSS WITH FOAM CORE

Heat loss X area = 9.66 X 61.02 = 590.58 BTU/HR

TOTAL HEAT LOSS PER HOUR WITH INSULATION AND STORM WINDOWS/DOORS

Walls	= 3709 BTU/HR
Attic	= 3010 BTU/HR
Floor	= 5110 BTU/HR
Windows	= 3850 BTU/HR
Doors	= 590.58 BTU/HR
Total	16,269.58 BTU/HR

SEASONAL HEAT LOSS OF INSULATED HOME

$$H = \frac{24hd\ (t_i - t_a)}{t_i - t_o}$$

$$H = \frac{24 \times 16,270 \times 246(70 - 44.5)}{70 - 7}$$

H = 38,879,648 BTUS per heating season.

UNITS OF FUEL USED YEAR HEATING SEASON

Natural Gas @ 75¢ efficiency = 50,200 cubic feet
#1 Heating Oil @ 75% efficiency = 381 gallons
#2 Heating Oil @ 75% efficiency = 370 gallons
Bottle Gas Propane @ 75% efficiency = 557 gallons
Electric @ 100% efficiency = 11,394 KW

ANNUAL COST OF FUELS OF INSULATED HOME

Natural Gas @ $3.00/MCF = $150.84
#1 Heating Oil @ .592/gallon = $225.55
#2 Heating Oil @ .66/gallon = $244.20
Bottle Gas Propane @ .558/gallon = $310.00
Electric Heat @ .05/KWH = $569.70

Let's calculate the cost of insulation --

Open Attic:	1,000 Sq. Ft.	@ 61¢ per Sq. Ft.	= $610.00
Net Walls:	868.8 Sq. Ft.	@ $1.02 per Sq. Ft.	= $590.78
Floor:	1,000 Sq. Ft.	@ 61¢ per Sq. Ft.	= $610.00
Windows:	11	@ $60.00	= $660.00
Doors:	3	@ $275.00	= $825.00
FIRST COST (FC)			$3,245.78

Calculate the Payback Period

$$PP = \frac{FC}{S}$$

Savings for natural gas = $906.36 = $PP = \frac{3245}{906.36}$ = 3.58 years

Savings for #1 Oil = $1356.27 = $PP = \frac{3245}{1356.27}$ 325 = 2.390 years

Savings for #2 Oil = $1468.86 = $PP = \frac{3245}{1468.86}$ = 2.20 years

Savings for Bottle Propane = $1823.55 = $PP = \frac{3245}{1823.55}$ = 1.78 years

Savings for Electrical = $3424.25 = $PP = \frac{3245}{3424.25}$ = .947 years

Since the insulation and double glazing has a probable life of 20 years, the savings during the 2nd through 20th year is your dividend.

Calculate the Return on Investment

$$\text{Yearly Depreciation Charge} = \frac{\text{FC (First Cost)}}{\text{EL (Estimated Life)}} = \frac{3245}{20} = \$162.25$$

$$\text{ROI\%} = \frac{\text{Saving} - \text{Depreciation}}{\text{First Cost}} \times 100\%$$

$$\text{Natural Gas} = \frac{906.36 - 162.25}{3245} \times 100\% = 22.93\%$$

$$\text{\#1 Oil} = \frac{1356.27 - 162.25}{3245} \times 100\% = 31.79\%$$

$$\text{\#2 Oil} = \frac{1468.86 - 162.25}{3245} \times 100\% = 39.87\%$$

$$\text{Bottle gas} = \frac{1823.55 - 162.25}{3245} \times 100\% = 51.20$$

Electric $= \frac{3424.25 - 162.25}{3245} \times 100\% = 100\%$

Calculate the Present Value and Benefit/Cost Ratio

PV = PWF 8% - 20 years X Annual Savings $

Natural Gas = 9.818 X $ 906.38 = $ 8,898.64
#1 Oil = 9.818 X $1356.27 = $13,315.85
#2 Oil = 9.818 X $1468.88 = $14,421.16
Bottle Propane = 9.818 X $1823.56 = $17,903.61
Electric = 9.818 X $3424.25 = $33,619.28

Thus, an investment of $3,345 now has a present worth of $8,898.64, $13,315.85, $14,421.16, $17,920.61 or $33,619.28, depending on the fuel used.

The Benefit Cost Ratio $= \frac{PV}{TC}$

Natural Gas $= \frac{\$\,8{,}898.64}{3245} = 2.74$

#1 Oil $= \frac{\$13{,}315.85}{3245} = 4.10$

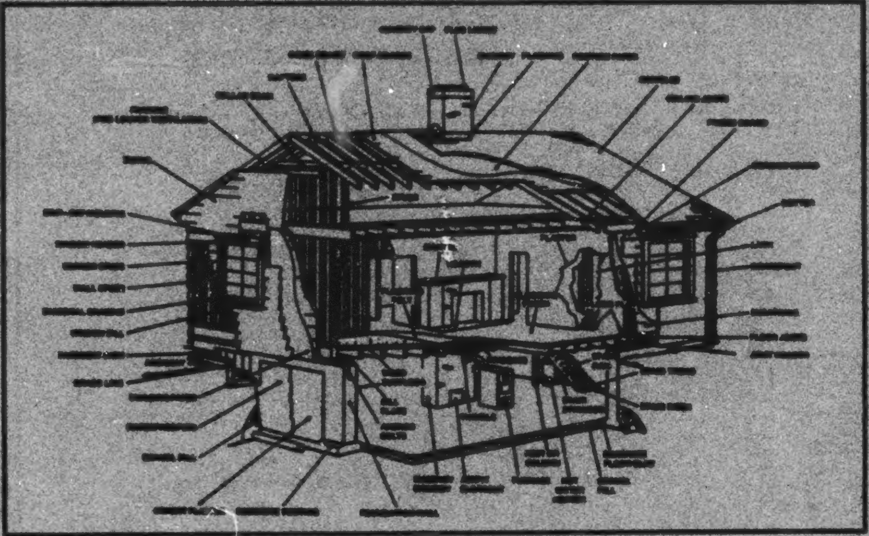
#2 Oil $= \frac{\$14{,}421.85}{3245} = 4.44$

Bottle Gas $= \frac{\$17{,}903.61}{3245} = 5.51$

Propane $= \frac{\$33{,}619.28}{3245} = 10.36$

A Benefit Cost Ratio greater than 1 is profitable!

The heating energy requirement for 5500 degree days (area average) is reduced by 86%.



Insulation Applications

worksheet 1 part 1

THE ATTIC – QUANTITY OF INSULATION AND COST

BEFORE YOU BEGIN

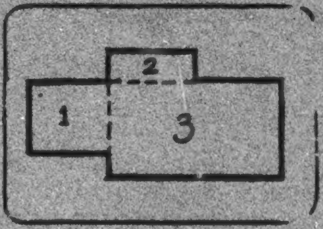
- Determine whether or not the joists are regularly spaced, either 16" or 24" "on center" (i.e. from center point to center point). If they aren't, you will have to use loose fill insulation or cut batts to size. If you choose this second approach, allowance must be made for wastage.
- If there are any vertical walls in the attic which adjoin a heated space, they must insulated (using batts). Don't forget to measure these walls.

1) Calculate the total area of the attic, in square feet.

______ x ______
length width

NOTE: If the attic is irregularly shaped, mentally divide it into 2,3, or more smaller rectangles. Calculate the area of each, then add these figures together.

2) Contact your insulation supplier to find out how large an area a single bag of your chosen type of insulation will cover, at the desired R-value. At the same time, find out the cost per bag.



______ sq.ft.
area covered per bag

$______
cost per bag

NOTE: If you are using batt type insulation over R20, you may need 2 complete layers of insulation. This second layer should always be purchased without a vapor barrier.

3) Total number of bags required = ______ sq.ft. (total area of attic) ÷ ______ sq.ft. (area covered per bag) = ______ (total number of bags (round upwards!))

4) Cost of insulation = ______ (number of bags) x $______ (cost per bag) = $______

5) If you are installing a separate vapor barrier, the total area of polyethylene required = ______ sq.ft. (total area of attic) x 1-1/3 (a factor to allow for overlap, wastage, etc.) = ______ sq.ft. (total area of polyethylene)

6) Cost of polyethylene = ______ sq.ft. (total area) x ______ (cost per sq ft. (from your supplier)) = $______ (cost of polyethylene)

7) Total cost of re-insulating the attic = $______ sq.ft. (cost of insulation) + $______ (cost of polyethylene) = $______ (total cost of project)

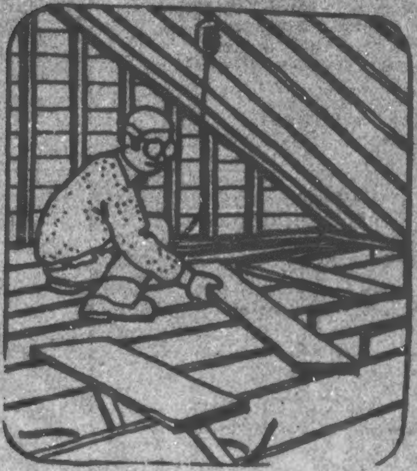
TWO REMINDERS BEFORE YOU START

- Remember that the goal is to form a complete blanket around the house. Search out the corners and spaces where heat may escape.

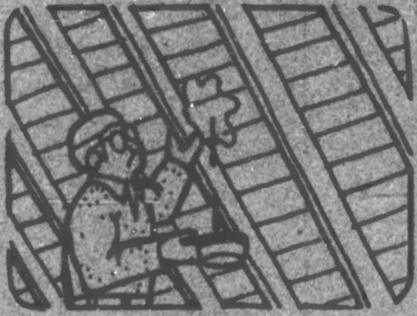
- Make sure you have familiarized yourself with the moisture control. Poor moisture control can cause problems.

HOW TO DO IT - STEP BY STEP

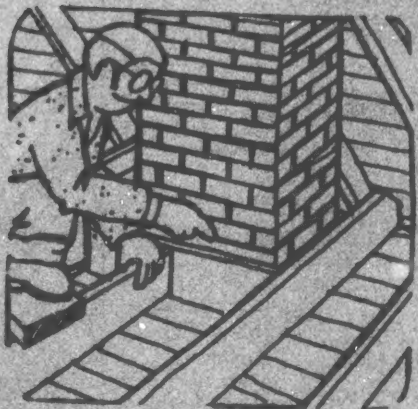
NOTE: If you live in a 1-1/2 or 2-1/2 story house, refer to page 71. first. If you have other problems, refer to page 73.



1) Install temporary lighting and flooring. Keep insulation wrapped until you are ready to install it. If possible, unwrap batts and blankets in the attic, since they expand and become less manageable after opening.



2) Check for leaks in the roof - wetness or water stains. If there are any, repair them first.



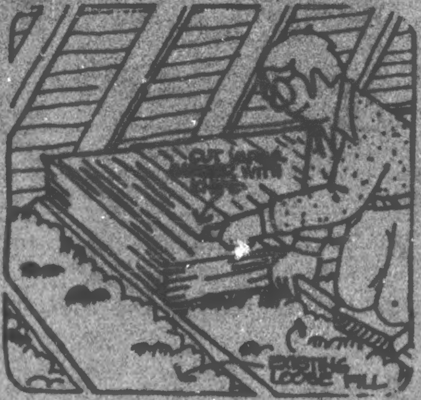
3) Check also for any obvious air leaks into the attic from inside the house. Seal all places where pipes or wires (careful!) penetrate the attic floor. Similarly, seal around ceiling light fixtures, the tops of inside walls, chimneys, hatches, and so on. Caulking, oakum, and polyethylene scraps are recommended, though polyethylene should be kept away from any direct source of heat such as a light fixture. It is especially important to ensure that no exhaust fans discharge into the attic. If they discharge to the outside, make sure the exhaust vent is not directly below the eave vents.

4) If you have done your best to cut down air leakage into the attic, and moisture problems persist, you may have to install additional

ventilation (see Section V on Condensation for details). In most cases, this should not be necessary.

5) EXISTING INSULATION: make sure it is dry and in reasonable condition. Whatever the kind, if it is not wet, leave it, adding new insulation on top. If it is wet, remove it altogether. Before adding new insulation, locate and eliminate the source of moisture.

6) VAPOR BARRIER



- If there is an existing vapor barrier, your job will be easy. Patch any obvious breaks in it, then proceed with the insulation. If you are using batts, try to get the "friction fit" type with no attached barrier. If you can only get the built-in vapor barrier type, then place the barrier on the upper side and slash it with a knife to allow air and vapor to pass.

- If there is no existing vapor barrier and no existing insulation, install a barrier as outlined below.

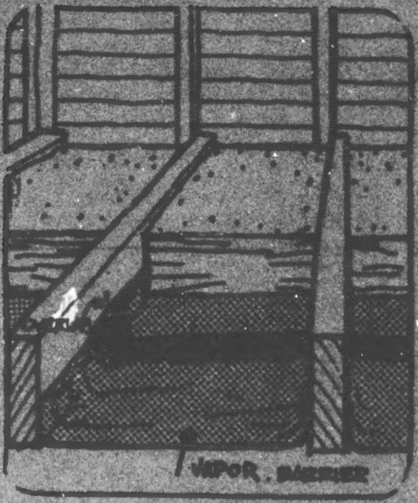
- In a case where there is no existing vapor barrier, but insulation is present, a barrier should never be placed on top of the existing insulation. Under some circumstances, it may be necessary to lift the insulation and put a barrier under it. However, if you have been having no moisture problems to date, if you are conscientious in sealing air leaks through the ceiling, and if humidity levels in the house are reasonable-then no problems should result from adding more insulation without any vapor barrier. Additional moisture protection can be achieved by painting the lower side of the ceiling with two coats of oil-based paint, a single coat of spar varnish, or applying vinyl wall paper.

  If you do not add a barrier, it is probably worthwhile to check the attic after a cold snap in January or February. Some frost buildup is to be expected, but if it is particularly heavy, you should work harder at sealing air leaks into the attic!

7) INSTALLATION OF VAPOR BARRIER (if required)

- The polyethylene should be cut into long strips about 4 inches wider than the joist spaces.

- Being careful to get right to the edges, the sheet should be laid down as shown. It should be stapled to the extent necessary to keep it from moving during installation of the insulation.



NOTE: The polyethylene should not be placed over the joists, as this could trap moisture between the plastic and the wood-an undesirable situation!

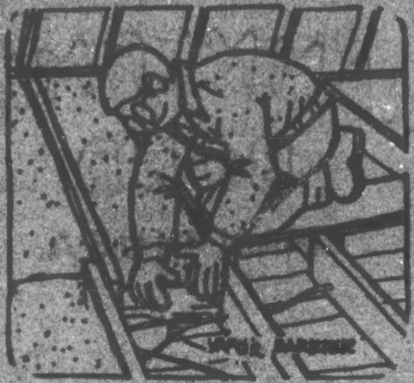
- Seams should be overlapped about 6" and, for optimal coverage, taped as well.
- Any obstruction in the attic, such as wooden braces or electrical wires (careful!!) will require cuts in the barrier. Seal these as much as possible with tape and small pieces of polyethylene.

8) INSTALLATION OF THE INSULATION

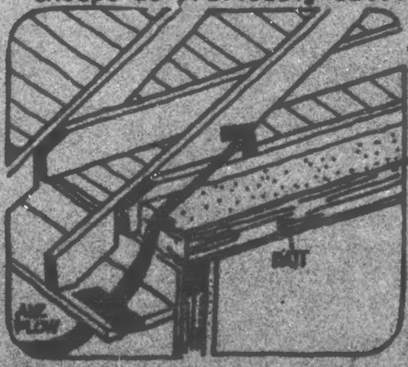
Depending upon the type of insulation you are using, you should follow the directions given in EITHER A OR B.

A. BATT OR BLANKET TYPE INSULATION

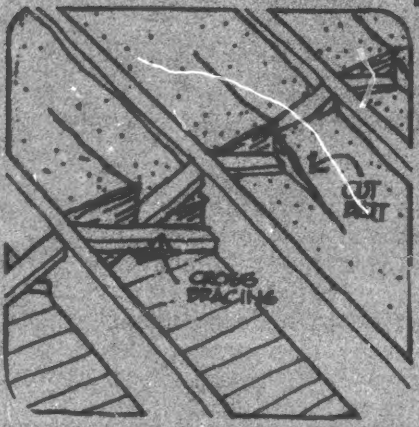
- Blanket type insulation is applied in basically the same way as the batt type to be described below. It may be precut with scissors, or cut on the spot. Start at one end of the attic, and unroll!!



- Batt type insulation is simply pressed into place between the ceiling joists. If you purchased the correct width, it will fit snugly. No stapling in place is necessary.
- If using a batt with attached vapor barrier, the barrier should be on the side towards the living area. Any tears in the barrier should be sealed with tape. Do not put this kind of insulation on top of existing insulation, except as previously outlined.

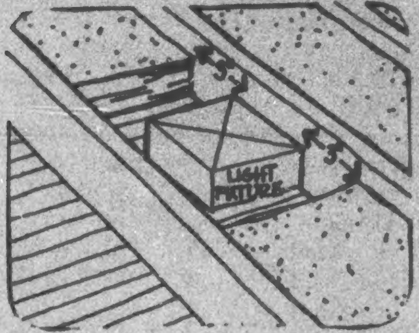


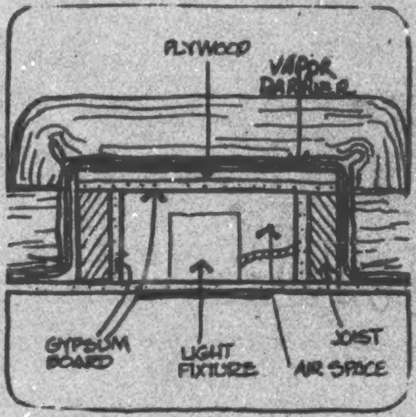
- Batts should not block the venting, but otherwise should extend as far as possible towards the eave.
- Butt the ends of different batts together as tightly as possible.



- Insulate tightly around cross bracing using diagonal cutting as illustrated. If possible, avoid cutting the vapor barrier.

- Do not insulate any closer than 3" from any recessed light fixtures or other heat sources such as an exhaust fan motor. Heat build up could lead to a fire hazard. On the other hand, the fixture will continue to be a major heat loss and possibly a moisture problem. The best solution is to eliminate the fixture if at all possible. If not, at least caulk any obvious openings with a heat resistant caulking compound.





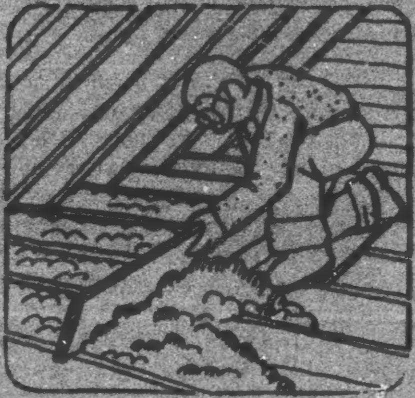
If the fixture does not touch any of the joists, and if any heat build-up could escape readily into the room below, you might consider building a box of plywood around the fixture. Line the inside of the box on all surfaces with gypsum board, leaving an air space all around the fixture. The box should then be insulated normally. Only undertake such a project if you are certain no problems will arise.

- Insulate around the chimney with non-combustible materials. Unfaced glass or mineral fiber is fine.

- If you are installing more than a single layer of insulation, and the first fills the joist space entirely, lay the second at right angles to the first. The second should, of course, have no vapor barrier.

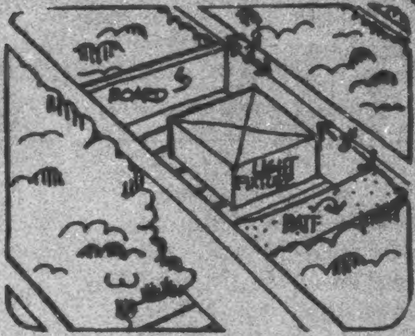
- Finally, don't forget to insulate and weatherstrip the hatch into your attic!

NOTE: The tar impregnated kraft paper vapor barrier attached to many batt insulations is a fire hazard if used in an exposed way. It also is not as complete or effective as the recommended 6 mil polyethylene.



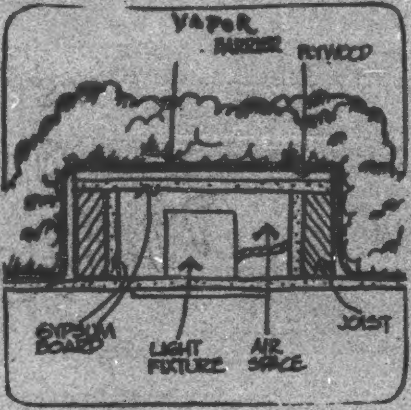
B. LOOSE FILL INSULATION

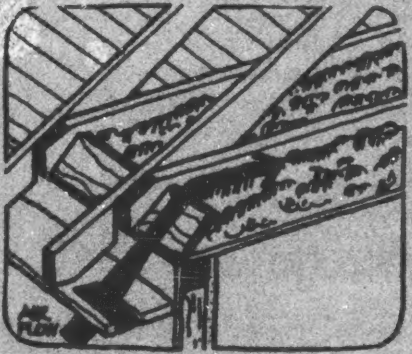
- Loose fill insulation is simply poured in on top of the vapor barrier. It is leveled off with a board or garden rake, as illustrated. If you are adding insulation to a depth greather than the height of the joists, the extra thickness makes leveling a bit difficult- but it will be worth it.



- Pour it to fill all nooks and crannies, but do not cover recessed light fixtures or exhaust fan motors. Heat build-up could become a problem. The insulation should be kept away from the fixture, either by using a batt or some wood framing as shown. The fixture will continue to be a major heat loss and possibly a moisture problem. The best solution is to eliminate the fixture if at all possible. If not, at least caulk any obvious openings with a heat resistant caulking compound.

If the fixture does not touch any of the joists, and if any heat build-up could escape readily into the room below, you might consider building a box of plywood around the fixture. Line the inside of the box on all surfaces with gypsum board, leaving an air space all around the fixture. The box should then be insulated normally. Only undertake such a project if you are certain no problems will arise.



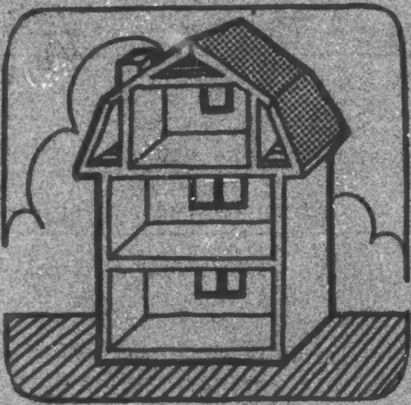


- At the eaves, caution must be taken to keep the insulation from blocking the ventilation and/or disappearing into the eave space. Batt insulation or a wood baffle may be used.

- The space between the chimney and the wood frame should be filled with noncombustible insulation such as glass or mineral fiber. Some of the loose fills are not suitable for this use.

- If your loose fill insulation is deeper than your joists, build a crib around the hatch into the attic to allow you to fill right up to the edge.
- Finally, don't forget to insulate (with a batt) and weatherstrip that hatch!

NOTE: If you presently have cellulose fiber, it is best to continue with it.



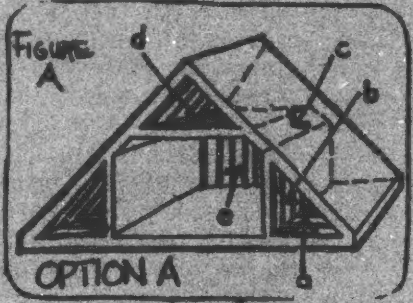
COMPLICATIONS –

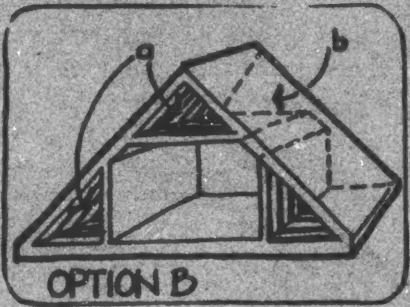
1½ OR 2½ STORY HOUSE

These buildings can be difficult! Insulation should be applied in either of two ways in order to create a complete heat-retaining envelope:

Option A
a) outer attic floor
b) the so-called "knee-wall"
c) short section of rafters
d) attic ceiling
e) end walls of attic room

Option B
a) full length or rafters
b) complete end walls of house





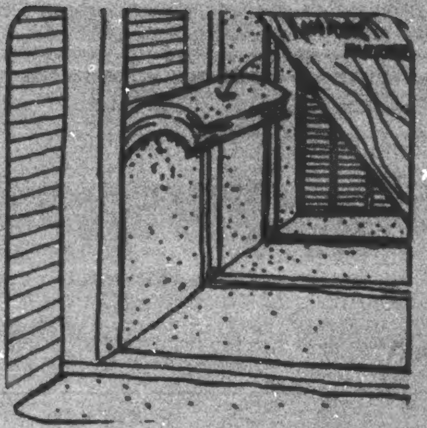
Method A is the preferred insulation program, since it cuts down on potential moisture problems, produces a more comfortable room (warmer walls), and reduces the total space to be heated.

If you can get into these spaces to work, you can do-it-yourself. Otherwise, a contractor will likely be necessary.

HOW TO DO-IT-YOURSELF

1) Treat the outer attic floor and the attic ceiling (designated (a) and (d) in figure A above) exactly as described for standard, unfinished attics on the previous pages.

2) Treat the end walls (designated (e) in Figure A) exactly as described in Part IV of this section (page 92).



3) The knee wall (designated (b) in Figure A) should be treated in much the same way as the unfinished attic floor described on the previous pages, making appropriate allowances for the fact that it stands upright:

- Batt insulation should be used in preference to loose fill (for obvious reasons).

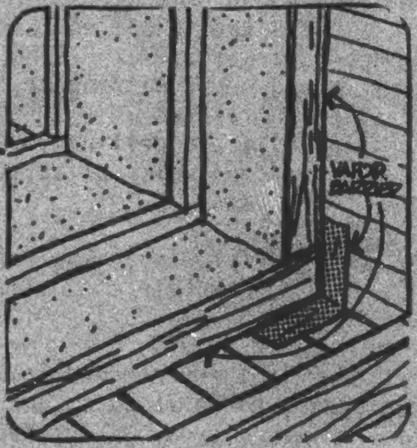
- Rigid-foam insulation (see Part IV) could theoretically be used. However, in confined attic spaces, batts are likely to be much more easily handled (and less expensive!).

- Before beginning, any obvious air leaks should be caulked.

- The vapor barrier should be applied on the warm side of the insulation.

- If batts with attached vapor barriers are being used, then special care should be taken at the joint with the attic ceiling. An additional strip of polyethylene should be applied to seal the joint, as illustrated.

- If there are any electrical outlets (careful!!) or pipes in the knee wall, then make sure you keep them on the warm side of the vapor barrier and insulation.

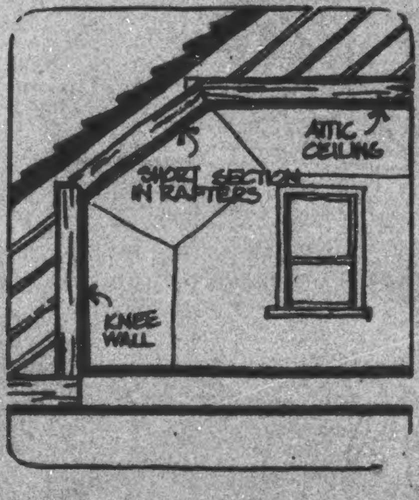


4) The section in the rafters (designated (c) in Figure A above) may be filled right up with insulation if:

- You currently have no moisture problems,

- You have sealed as many air leaks into the attic space as possible,

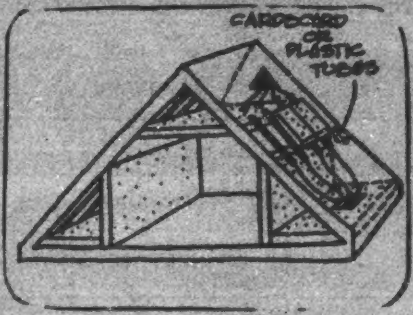
- Humidity levels in your house are not excessive (see condensation section of this unit).



If, however, you are unsure about whether or not moisture in the attic will be a problem, you should probably leave some ventilation space between the insulation and the roof above it.

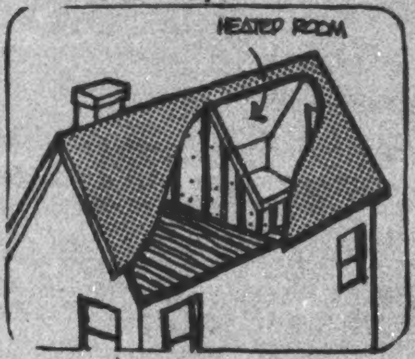
Remember to place the vapor barrier on the inward side of the insulation, making it nearly continuous with the barriers above and below.

- You can also put tubes of some sort (plastic or cardboard) in the section along the rafters to ensure adequate ventilation. That section may then be completely packed with insulation.

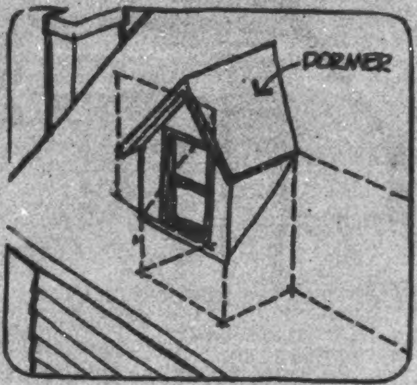


OTHER COMPLICATIONS

- Some houses will have a wall in the attic that adjoins a heated space. Insulate it as you would a knee wall (see page 72).



- Many houses with accessible attics also have dormer windows.
    - The walls shaded in the illustration may be insulated with batt insulation, as described for the knee wall (see page 72). As always, the vapor barrier should be on the heated side of the insulation, overlapping at joints and corners.
    - The remaining walls and the dormer ceiling are much more difficult. A contractor may be able to re-insulate it for you. If you're having a contractor do work on the walls anyway, it may be worth your while to have the dormers done at the same time.



- Some houses will have the attic floored over, even though it's not used as living space.
    - You can re-insulate it yourself by lifting the floor boards and treating it as you would an unfinished attic.
    - You can have a contractor blow loose insulation through a few small holes into the sub-floor space, completely filling it up. Before he begins, calculate the R-value that you expect

to achieve, given the space between the attic floor and the ceiling below. Then, check the bags of insulation to be used. They should indicate what area one bag will cover at the selected R-value. You and the contractor should then agree on the total number of bags to be used. There is no way of installing a vapor barrier in this case. If one does not already exist, it should be acceptable to install the insulation if the following conditions are met (even if there is a vapor barrier, these conditions are worthwhile!):

1) there is no evidence of existing moisture problems

2) humidity sources in the house are reasonable

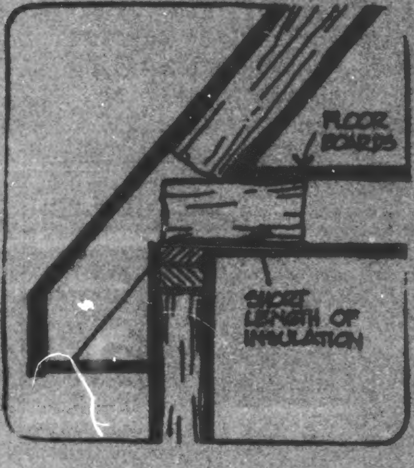
3) the floor above the insulation will allow air to pass

4) an effort has been made to plug all air leaks into the attic from the house below

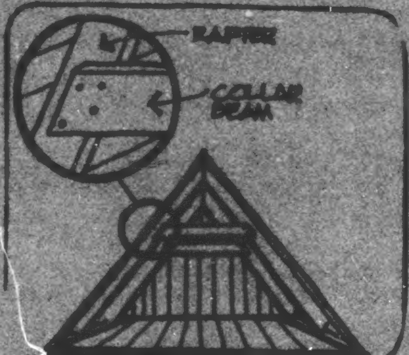
5) the attic is adequately ventilated.

When there is no vapor barrier, added protection can be achieved by painting the underside of the ceiling with a coat of spar varnish or two coats of oil based paint.

- If you expect to finish your attic some day, you may want to insulate between the rafters instead. Just remember that the process is somewhat difficult and may create moisture problems. Furthermore, until you actually start using the attic, you'll be heating a lot of unused space. If you choose to do it, the steps to take are briefly as follows:

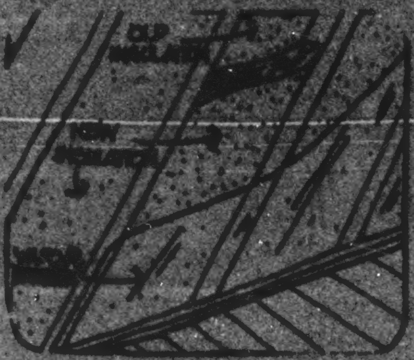


1) The wall space immediately below the attic floor must first be insulated. This will be easy if the floor boards can be lifted. Simply pack the space with batt type insulation as shown.



2) Install collar beams between every pair of rafters, as illustrated.

3) If there is already some insulation between the rafters and between the end wall studs, move it to the



back of the rafter or stud space, and destroy the vapor barrier. Next, apply the new insulation (it should be either glass or mineral fiber "friction fit" batts) as illustrated. Finally staple a continuous polyethylene vapor barrier to the rafters and studs.

4) Insulation between the collar beams is applied from below in much the same way, with a continuous polyethylene vapor barrier applied last. If, however, the collar beams were there before this operation and have already been insulated, and if there is access to the upper portion, then the space may be re-insulated like a normal attic.

5) Finally, block off and seal any ventilation into your attic, which is now heated!

part 1b

HOW TO INSULATE THE ATTIC —

IF IT CAN'T BE EASILY WORKED IN

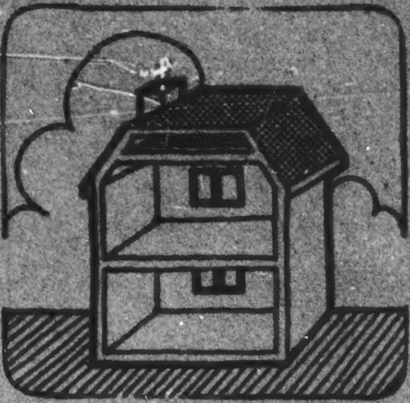
NOTE:

- If the only problem is that there is no access point, but the attic would be large enough to work in if you could get to it, Part IIA should be used.
- If the attic is both cramped and without an access hatch, don't give up. A hole might possibly be cut in the ceiling in an out of the way place, such as a cupboard (make sure that no structural supports are cut!) Alternatively, a possible access point might be through outside vents, either existing or new ones. So don't give up-read on.

This section looks at two types of situations, in two separate sub-sections:

1) THERE IS AN ATTIC, BUT IT IS TOO CRAMPED TO WORK IN

2) THERE IS REALLY NO ATTIC

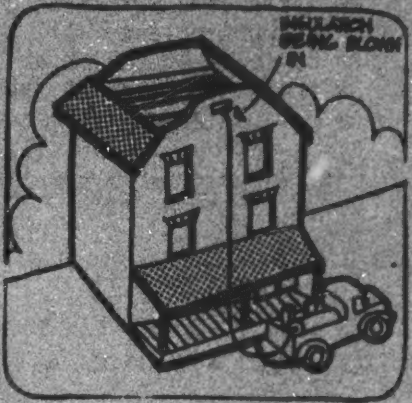


ATTIC TOO CRAMPED

You have two choices:

a) It may be possible to insulate outside the building, on top of the existing roof. See the "second case" below.

b) It may be possible to have a contractor "blow in" loose fill insulation. Before he begins, calculate the R-value that you expect to achieve. Then, check the bags of insulation to be used. They should indicate what area one bag will cover at the selected R-value. You and the contractor should then agree on the total number of bags to be used.



There will likely be no way of installing a vapor barrier in this case. If one does not already exist, it should still be acceptable to install insulation if the following conditions are met (even if a barrier is present, these points are worthwhile):

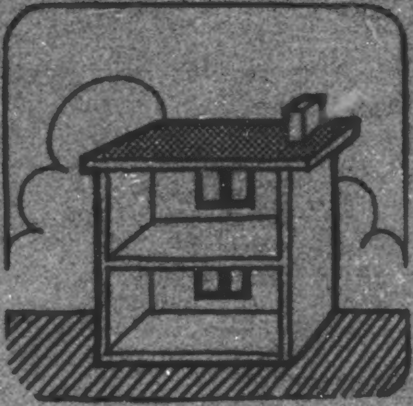
- there is no evidence of existing moisture problems
- humidity sources in the house are reasonable
- any air leaks through the ceiling, into the attic are sealed
- the attic is adequately ventilated.

When there is no vapor barrier, added protection can be achieved by painting the ceiling below the attic with a coat of spar varnish, or two coats of oil-based paint.

You should ensure that the contractor makes provision to stop insulation from entering the eave and blocking the ventilation. Furthermore, if any recessed light fixtures are present in the area to be filled, make sure precautions are taken, as outlined on page 70.

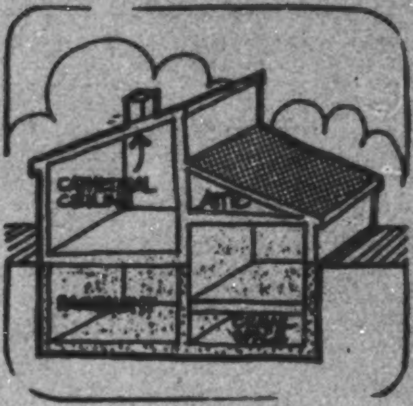
Finally, if there are any vertical walls in this attic space ("knee" walls, dormer windows, etc.) they likely cannot be handled by this method of blow-in insulation. Consult your contractor for details.

THERE IS NO ATTIC



A house (or any portion of a house) with a flat roof, a cathedral ceiling, or some other "atticless" construction is likely to be a difficult case, almost certainly requiring the services of a qualified contractor. Three options are available:

a) If the roof has exposed joists or beams (usually left exposed for decorative purposes) it may be possible to close the space in, creating a new ceiling. Framing may need to be added; then insulation batts; next an extremely effective vapor barrier, blocking virtually all air flow; and finally the new ceiling. If there is an existing vapor barrier, it may cause problems unless it is destroyed or the new barrier below is much more effective than the original. In all cases, moisture could cause difficulties in such a project. Review the section on moisture control before considering this option.



b) The existing space between the ceiling and roof can be blown full of loose fill insulation by a contractor. Since this eliminates and ventilation altogether, it is not generally a recommended practice for existing homes. If you do choose this insulation program, make sure air leaks into the ceiling are sealed and the vapor barrier is intact. Have the contractor blow in cellulose fiber (because of its high density) at a density of 3-4 lbs. per cubic foot.

c) Insulation may be added on top of the existing roof. This option is likely best, and is particularly attractive if the existing roofing needs replacing. It should, nevertheless, be undertaken by a qualified roofing tradesman.

The job can be done in a number of different ways, using a number of different materials. However, the most suitable insulation material is generally extruded polystyrene. Consult with your roofing contractor regarding the best approach.

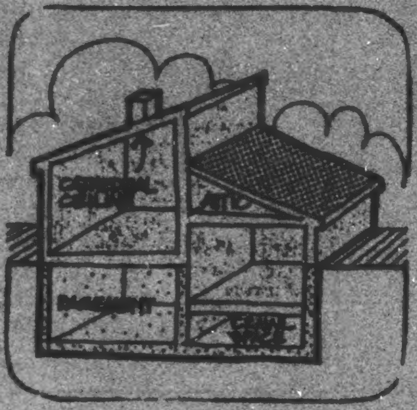
In all cases, make sure that you hire a qualified contractor.

part 2

HOW TO INSULATE BASEMENTS, CRAWL SPACES, OPEN OR CONCRETE SLAB FOUNDATIONS

This section is divided into four sub-sections, by the type of foundation:

A. Basements.......... 79
B. Crawl Spaces....... 90
C. Open Foundations... 92
D. Concrete Slab Foundations........ 92



A BASEMENT

The basement is one of the areas of highest heat loss in the house. It is clearly one of the most neglected.

There are two ways of insulating the basement inside or outside.

WHICH APPROACH-INSIDE OR OUTSIDE?

INSULATING INSIDE involves installing a wood frame wall inside the foundation, and adding insulation to it. If possible, it should not be undertaken in basements with a moisture problem.

If there is such a problem, however, and outside insulation is not feasible, then corrective measures can be taken to allow inside work.

The general advantages of inside insulation include:

1) It can be incorporated into a program of refinishing your basement.

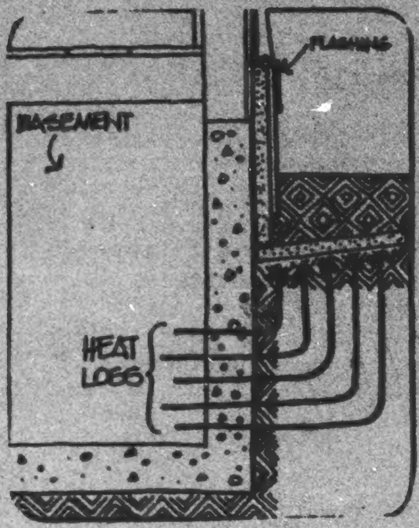
2) The basement walls will be warmer, and hence the room more comfortable.

3) The insulation may provide some sound insulation.

4) The work can-be done any time of the year - winter or summer.

INSULATING OUTSIDE involves laying two slabs of rigid insulation as shown in the illustration. Heat loss from the lower basement tends to escape almost vertically, as indicated. The nearly horizontal slab prevents this escape.

Some sort of flashing must be attached as indicated in the drawing, in order to keep water out from behind the insulation.



Unfortunately, if your house has brick or stucco siding, it may not be easy to attach this flashing in a way that it will be water tight. If this is the case, it is preferable to insulate inside.

Otherwise, the general advantages of outside insulation include:

1) The outside wall tends to be more regular, and so easier to insulate. Some parts of a basement wall cannot be done from the inside (for instance, where a partition joins the wall).

2) Basements with moisture problems should not be insulated inside, and the problem should be corrected.

3) Unless the inside basement is to be refinished anyway, outside insulation is probably cheaper and easier, and can be just as effective.

4) No inside space is lost.

5) The soil adjacent to the basement wall below the horizontal piece is kept above freezing, which promotes drainage through the soil. Then insulation is applied inside, however, the outside soil may freeze, increasing the possibility of frost heave.

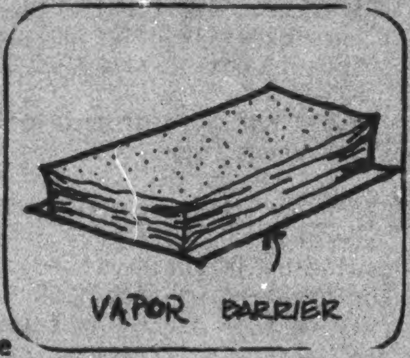
In most cases, the outside approach will prove to be the best from a technical point of view. However, choose which of the two approaches you prefer, then follow the appropriate "How-to" instructions beginning immediately below for inside insulation, or on page 85 for outside insulation.

HOW TO INSULATE INSIDE THE BASEMENT

WHAT INSULATION TYPES ARE SUITABLE

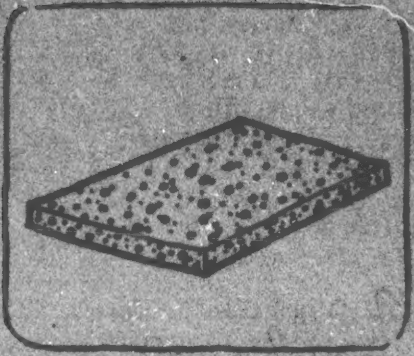
There are two possible choices:

BATT OR BLANKET TYPES: flexible slabs or rolls of lightweight glass or mineral fiber. Available with or without a vapor barrier on one side.



RIGID FOAM TYPE: rigid slabs made of various plastic materials with high insulating value (polystyrene is the best choice).

In choosing between the two types, the following factors should be considered:



- **BATT/BLANKET INSULATION**
  - These materials are easy to work with and reasonably inexpensive.
  - If using batts or blankets, glass fiber is often preferable to mineral fiber in basement applications because of its superior handling characteristics (though mineral fiber may give you a higher R-value per inch).

- **RIGID FOAM INSULATION**
  - The rigid foam insulations generally have a higher R-value per inch than the batts and as such will require less basement space and a thinner supporting framework. They are less prone to moisture related damage than the batts, but are a fire hazard if used in exposed or semi-exposed applications. If used, they must be covered by 1/2 inch gypsum board (or with plaster).
  - If using rigid board, polystyrene represents the best value. The white material commonly called "styrofoam" is more correctly called-polystyrene beadboard. "Styrofoam" is a registered trade mark of a particular company producing blue extruded polystyrene. The choice between the two polystyrenes should be based on price per unit of R-value, thickness of the available space, and on the fact that beadboard is more affected by moisture problems. (As stressed above, however, basements with a moisture problem should ideally be insulated outside!).

    Where available, phenolic foam could be considered as an alternative because of its higher fire resistance, though it too is affected more by moisture than the extruded polystyrene. The final option, polyurethane slabs, tends to be more expensive than polystyrene. Furthermore, the material ages if not entirely covered with some sort of metallic skin.

Choose the type of insulation you require, and determine the exact thickness required.

WHAT VAPOR BARRIER SHOULD BE USED?
The recommended choice of vapor barrier for use with all types of insulation is the 6-mil polythylene, available in continuous 12 ft. (or greater) widths. The 6-mil thickness is both durable and unlikely to tear during installation. It is not recommended that you use batts with attached vapor barriers, since it is possible to use the far more effective continuous polyethylene.

worksheet 11

INSIDE THE BASEMENT QUANTITY OF MATERIALS AND COST

1) LUMBER

Either 2 x 4's (24" spacing) or 2 x 2's (16" spacing) may be used. If using insulation under 2 inches thick, the 2 x 2 is recommended. Otherwise, 2 x 4's will be easiest to handle. (2 x 2's may be spaced at 24" O.C. if applied directly against the wall.)

STUDS
Number of studs required (assume one stud every 16" or 24" of wall, with a double stud in each corner) = ☐

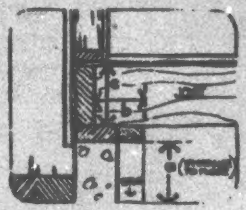
Length of each stud =
Height from the floor to the bottom of the joists minus 3 inches = ☐ ft. in.

TOP AND BOTTOM PLATES
Total length required =
2 x total length of wall to be insulated = ☐ ft. in.

Contact your dealer for cost figures. Total Cost = ______

2) INSULATION

Total height of insulation =



a + b + c (refer to diagram)= ☐ ft. in.

Total area of insulation =

______ x ______ = ☐ sq.ft.
height of insulation, length of walls

NOTE:
The most convenient insulation to use between the joists is the batt type. If rigid foam is used on the wall below, separate calculations of the quantities of each type to be ordered are required.

Total cost of insulation =

______ sq.ft. x ______
total area, cost per sq. ft.

3) VAPOR BARRIER:

Total area required same as for insulation = ☐

Total cost =

______ sq.ft. x $ ______ = ☐ $
total area, cost per sq. ft. (from your dealer)

NOTE:
Remember that if the walls are damp, you will need a second barrier of the same size to be placed adjacent to the concrete wall.

4) FINISHING PANELS:

Total Area Required =

______ x ______ = ☐ sq.ft.
height from joists to floor, length of walls

Total Cost =

______ x ______ = ☐ $
total cost, cost per sq. ft. (from your dealer)

5) TOTAL COST =

______ + ______ + ______ + ______ = ☐ $
cost of lumber, cost of insulation, cost of vapor barrier, cost of paneling

If the basement wall is damp, and you must insulate inside, the wall will need to be covered with another moisture barrier before adding the insulation. For this purpose, 2 mil polyethylene should be used. It should only extend up the wall to the ground level, since the above ground portion of the foundation is not normally a source of moisture.

Once you have selected a type of insulation and vapor barrier, you should complete Worksheet II, which will help you to calculate the necessary quantity and the approximate cost of the materials required. Have your order delivered, since insulation is bulky.

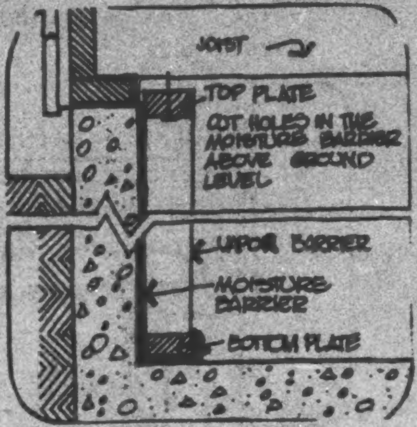
When you are ready to begin the actual job, the detailed instructions begin on page 83.

HOW TO INSULATE INSIDE THE BASEMENT-STEP BY STEP

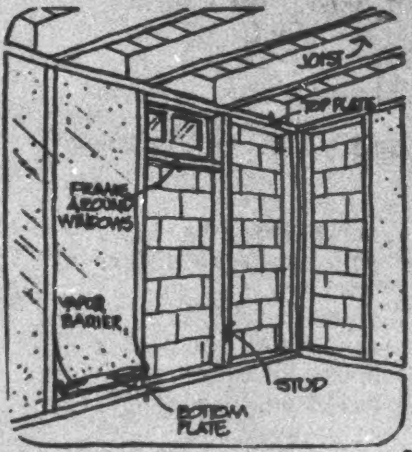
NOTE: When insulating a basement inside it is important to make sure that the batts are tight against the foundation wall.

Before you begin, be sure to caulk any cracks between the foundation and the sill.

1) If the walls ever become damp, then the portion below ground should, as a minimum, be treated with water-proofing chemical before proceeding. Even better, cover that same portion with a 2 mil polyethylene moisture barrier. The easiest way to install such a barrier is to attach the polyethylene to the header joist at the top. The portion of the barrier above ground can then be partially cut away to allow any moisture which might become trapped in the insulation to escape. Next, extend the sheeting right to the floor, such that the bottom edge stretches under the bottom plate of the framework, then back up to attach to the top of the plate, as shown.



2) Install the new frame wall as illustrated using 2 x 2's or 2 x 4's. First nail the bottom plate to the floor with concrete nails (easiest if you drill small holes first) and the top plate to the joists. Where the wall runs parallel to the joists, you will have to build in some sort of nailing support for the top plate (the approach you use will be dependent upon your particular house-improvised!). Then install the studs 24 inches "on center" (i.e. from the center of one stud to the center of the next) for 2 x 4's, or 16" on center for 2 x 2's. Make-sure the studs are perfectly verticle so that the insulation will fit in snugly.



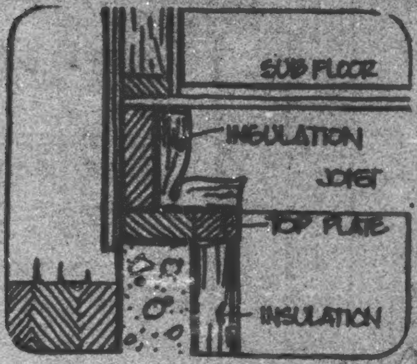
If you are using insulation thicker than the depth of the studs, you can build your wall frame out from the wall a bit to supply the necessary depth.

3) Install the insulation tightly between the studs as shown. If you are using rigid insulation be careful to keep it away from any flame source while you work with it.

When batts with an attached vapor barrier are used, (not the recommended approach), staple the flanges to the studs, overlapping whenever possible. Otherwise, install the polyethylene vapor barrier along the inside face of the studs using staples. Leave enough extra at the top to extend into the space between the joists as indicated in step 4. Tape any breaks in the barrier. All joints should be overlapped six inches and taped as well. Where possible, the joint should occur over the stud where it can be stapled.

4) If you never have moisture leakage on the wall just insulated, then the crack between the bottom plate and the floor should be caulked to prevent air entry.

5) If moisture is a serious problem in your basement you may want to leave a 4" to 6" space between the bottom plate & insulation. The entire bottom plate should also be wrapped in polyethlene.



6) Apply batt insulation to the joist space as shown. The flanges of an attached vapor barrier should be stapled down. Better still, extend the polyethylene from below into the space. Be imaginative in your use of polyethylene scraps, tape, and staples in order to get a tight seal.

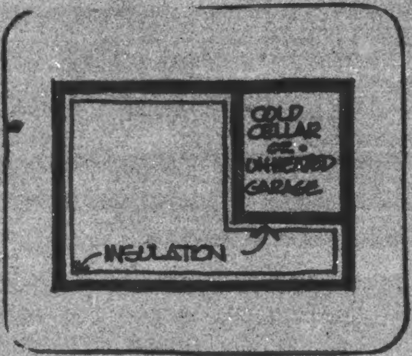
7) Finally, nail up the finishing surface (which must be gypsum board or plaster if rigid insulation was used. Make sure this fire break is tight against the insulation!).

COMPLICATIONS

- The Wall Space is Interrupted by Pipes, Ducts, Electrical Boxes or Outlets:
  - If possible push the insulation and vapor barrier behind any such obstructions so that they sit on the warm side. Turn off the power before working around electrical boxes.
  - If any obstruction (other than water pipes) generates significant quantities of heat, then do not insulate around it. Allow the heat to escape, rather than build up to potentially dangerous levels.
  - Avoid working around the main electrical panel for the house. Even when the power to the rest of house is off, the panel will still be "live".

- The Basement Wall is Interrupted by a Window:
  - Frame around the window as shown in the diagram on page 83. Seal the point where the frame adjoins the wall with caulking compound, and then insulate as before. And don't forget the storm windows!
- Part of the Basement is a Cold Cellar or an Unheated Garage:
  - The insulation should be applied to the cold cellar or garage wall as if it were an external wall. The doorway in from the basement should be weatherstripped and insulated if it isn't already. Finally, the ceiling should be insulated as described on page 98.

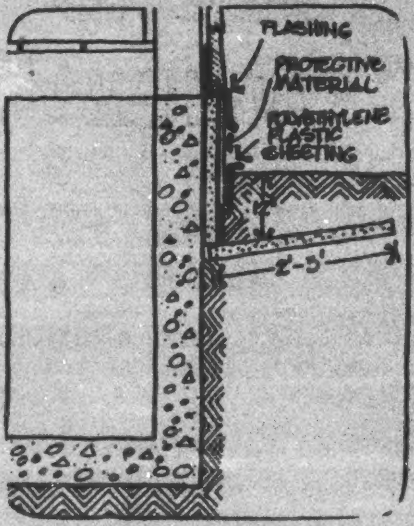
If it's your cold cellar, rather than your garage, there will be an added benefit - it will be cooler!



HOW TO INSULATE OUTSIDE THE BASEMENT

WHAT INSULATION TYPE SHOULD BE USED

There is really only one choice - rigid extruded polystyrene. This product must be distinguished from the white board which is commonly called "styrofoam". This is an incorrect name - the proper name is polystyrene "beadboard". The term "Styrofoam" is a registered trade mark which properly refers to a particular company's version of extruded polystyrene. This product is blue.



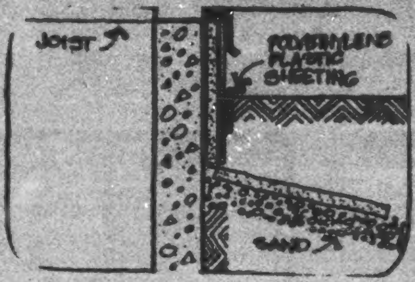
Extruded polystyrene not only has a high insulating value, but has a very high resistance to water absorption. As such, it is well suited to this purpose.

The insulation used should be at least 2 inches thick, and the horizontal section should be at least 2 feet wide. Even better would be a 3 inch thickness and a 3 to 4 foot width. The decision about what size to use should be based upon the climate in your part of the country and upon your personal finances.

It is important to minimize the amount of water flowing down your basement wall. It is recommended that the ground above the insulation slope away from the house, and that eave troughs be installed to collect the water from the roof and direct it away from the house.

The portion of the insulation above the ground should be covered with fire resistant protective material. Since it must extend a few inches underground for support, the material should also be water resistant. One quarter inch asbestos board, latex based stucco, or expanded metal lathing with cement parging are the recommended materials.

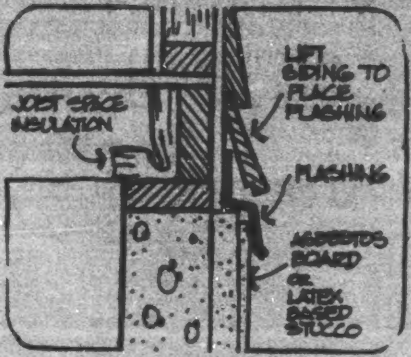
The top of the insulation should be protected by some sort of metal flashing, to prevent water getting behind the insulation, consult with your building materials supplier to determine the type of flashing most suitable for your needs.



NOTE:
If you live in an area of excessive rainfall where dampness (not freezing) is the major problem, the insulation should slope away from the foundation and drainage must be insured by placing the insulation on several inches of sand.

Finally, the portion of the vertical piece of insulation that is below ground should be protected from the soil by a piece of heavy polyethylene plastic sheeting. The function of this material is to allow the ground around the insulation to settle without damaging it.

Depending upon how the junction between the foundation and the joists is constructed, it may also be necessary to add some insulation inside, in the joist space. Put simply, if there is a gap between the lowest point of wall insulation and highest point of basement insulation, then that gap should be filled. Glass or mineral fiber batts are best for this purpose. They may be used with or without an attached vapor barrier (if used without, a separate polyethylene barrier should be used).


LIFT SIDING TO PLACE FLASHING
JOIST SPACE INSULATION
FLASHING
ASBESTOS BOARD OR LATEX BASED STUCCO

Worksheet III will help you to calculate the necessary quantity and the approximate cost of the materials required. Have your order delivered, since insulation is bulky.

When you are ready to begin the actual job, the detailed instructions begin on page 88.

worksheet III

OUTSIDE THE BASEMENT QUANTITY OF MATERIALS AND COST

1) INSULATION - POLYSTYRENE

Height of foundation above ground = ____ ft. ____ in.

Width of vertical piece of insulation

____ + ____ = ____ ft. ____ in.
height of foundation above ground + depth of extension underground

Width of horizontal piece of insulation (your choice) = ____ ft. ____ in.

Total length of exterior walls to be insulated = ____ ft. ____ in.

Order sufficient pieces in each of the two widths to extend the full length of the exterior walls. You may have to buy oversized pieces, then cut them to the correct width.

Total cost (from the supplier = $ ____

2) INSULATION - BATT (if required for the inside joist space)

Width of insulation required = ____ ft. ____ in.

Total length of interior walls to be insulated ____ ft. ____ in.

Total area of insulation required =

____ x ____ = ____ sq.ft.
total width x total length

Total cost of batt insulation

____ sq.ft. x ____ = $ ____
total area x cost per sq.ft.

3) PROTECTIVE MATERIAL

Height of the foundation above the ground = ____ ft. ____ in.

Width of the protective board required =

Height of the foundation above ground + 4 inches = ____ ft. ____ in.

Total length of exterior walls to be protected = ____ ft. ____ in.

Total area to be protected =

____ x ____ = ____ ft. ____ in.
width required x length required

If using asbestos board, order sufficient pieces in the correct width to extend the full length of the exterior wall.

If using latex based stucco, order sufficient to cover the total square footage.

Total cost (from your dealer) = $ ____

4) FLASHING

Total length of flashing required =
Total length of exterior walls to be insulated = ____ ft. ____ in.

Total cost of flashing =

____ x $ ____ = $ ____
total length x cost per ft.

5) POLYETHYLENE SHEETING

You will need to purchase enough polyethylene to extend the full length of the exterior walls to be covered, at a width of 1 foot.

Total cost (from your dealer) = $ ____

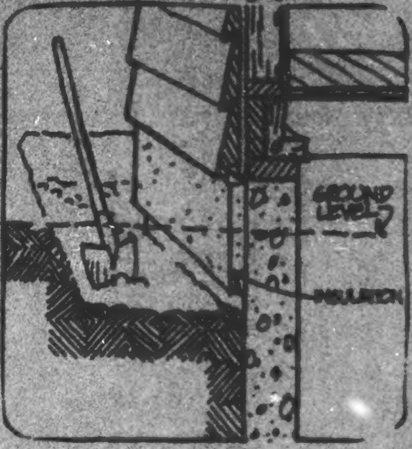
6) TOTAL COST OF PROJECT =

$ ____ + $ ____ + $ ____ +
cost of polystyrene insulation + cost of batt insulation (if any) + cost of protective exterior

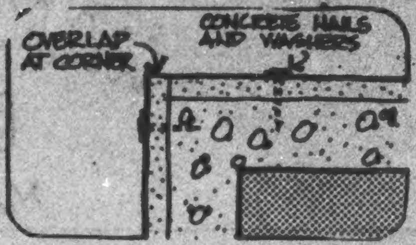
$ ____ + $ ____ = $ ____
cost of flashing + cost of polyethylene sheeting

HOW TO INSULATE OUTSIDE THE BASEMENT-STEP BY STEP

1) Digging the hole: The vertical piece of insulation should extend a minimum of 12 inches into the ground. The second piece should be sloped towards the building (to promote drainage through the unfrozen soil adjacent to the basement wall) such that it drops about 2 inches for 2 foot piece of insulation or 3 inches for a 3 foot one. In short, you could be digging between 9" and 12" deep around your entire house - a big job. Don't make it bigger by oversizing your hole.



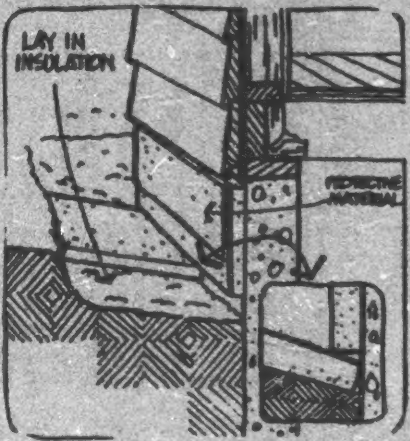
2) Apply the vertical polystyrene first, attaching it to the wall with concrete nails driven through a washer on the outer surface of the polystyrene. This job will be made easier if you drill small guidance holes for the nails beforehand. Overlap the insulation at corners.



3) The exterior protection is applied next, from the top of the insulation to a point about 4 inches below ground level:

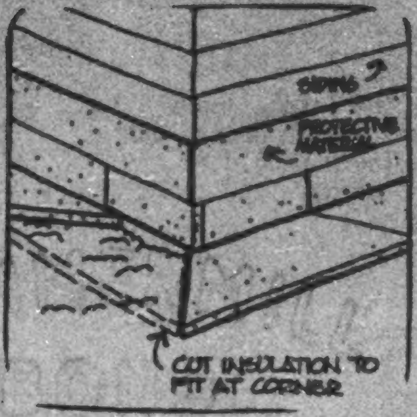
a) f using the latex based stucco (the easiest and cheapest), simply follow the directions supplied by the manufacturer. The application is a two-stage process requiring no special skills.

b) f using the asbestos board, you may want your dealer to cut it to size, since the material is rock hard. It must be applied using nails, as outlined above for the insulation. Remember, however, that the flashing at the top and the soil at the bottom will help to keep the board in place. so the nailing can be minimal.



4) Level off the soil in the hole so that it slopes uniformly down to the low point. A handy way of achieving this is to have a 2 x 4 of appropriate length handy. Simply drag it along the bottom of the hole, leveling off all the uneven sections.

5) Lay the insulation on the ground in such a way that it butts tightly against both the basement wall the the underside of the vertical polystyrene, as detailed in the inset.



6) At the corners, cut the insulation specially to fill the entire space, as shown.

7) Place the polyethylene plastic sheeting against the protective board and the insulation. It need not be held securely in place. Refill the hole, very gently at first so as to not damage the insulation - or the polyethylene. Make sure the ground, when the hole is finally filled, slopes away from the insulation, as will the addition of eave troughing. It is important not to direct excess surface water towards the foundation.

8) Apply the flashing according to the manufacturer's instructions. Remember that it must be applied so as to prevent any water runoff from getting in behind the insulation.

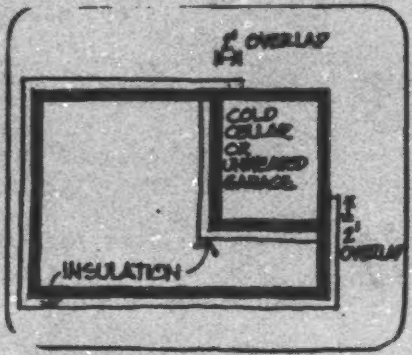
9) The filled hole may be covered with any type of surface - patio stones, grass, a garden, or whatever you please. Shrubbery with deep roots should, however, be avoided.

10) If insulation is necessary inside, between the joists, then apply it as described in step (4), page 84. Pay particular attention to keeping the vapor barrier tight. For this purpose, a separate polyethylene barrier is preferable to the type attached to the batts.

COMPLICATIONS

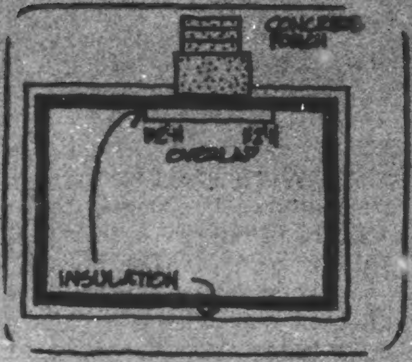
- Part of the basement wall is outside a cold cellar or an unheated garage:

    - The insulation should be applied inside the basement, against the cold cellar or garage walls. They should be treated as if they were exterior walls. The doorway in from the basement should be weatherstripped and insulated if it isn't already. Finally, the ceiling should be insulated as described on page



    The outside insulation around the rest of the basement should be extended 2 feet beyond the inside wall junction (as illustrated) to minimize heat loss at these points.

- There is a concrete porch butted against the basement wall, a paved driveway, or some other obstruction:

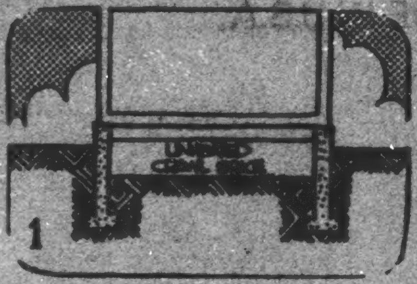


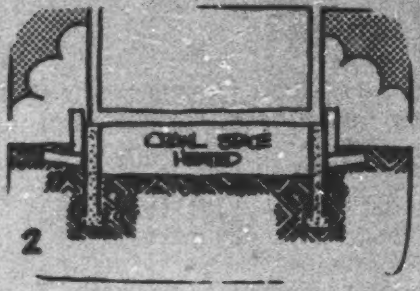
- Once again, the insulation should switch to the inside around these obstacles. There should be at least 2 feet of overlap, to ensure a good heat seal.

B CRAWL SPACE

Theoretically, a crawl space could be insulated in either of two ways:

1) The house floor above it could be insulated to keep heat from getting into the crawl space in the first place, or





2) The walls of the crawl space could be insulated, creating an additional heated area.

If the crawl space moisture level is so high that it requires summer and winter ventilation (even with a vapor barrier on the floor), then the unheated crawl space approach must be used. Otherwise, insulating the walls is generally recommended. The most important reasons for this preference are:

1) Heating ducts and pipes in the crawl space don't need to be insulated.

2) The walls can be insulated on the outside:

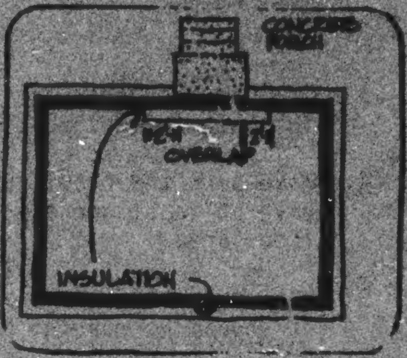
   - This reduces the internal moisture problems which can develop in damp crawl spaces.

   - This also prevents possible frost heave by keeping the soil below the insulation warm (an unheated crawl space, or one insulated inside, will be surrounded by frozen ground).

Choose which approach you prefer, then follow the appropriate detailed instructions below.

HOW TO DO IT-HEATED CRAWL SPACE

1) Insulate the outside wall exactly as directed for the outside basement wall on page 85.



2) If outside obstructions (a porch, a paved driveway, etc.) make it impossible to completely encircle the crawl space from the outside of the house, then the inside of the wall may be insulated at those points. Make sure the inside and the outside portions overlap by at least 2 feet, as illustrated.

The insulating material to use is extruded polystyrene. It should be applied in the same manner outlined for inside the basement, on page 79. The job will be tricky in such cramped quarters! In particular, remember the gypsum covering for the insulation - you'll have a fire hazard if you forget.

3) If there is no vapor barrier on the crawl space floor, add one. The barrier should be protected by covering it with a 2 inch layer of sand.

4) If your crawl space doesn't open into a full basement it should have summer ventilation (about one square foot for every 500 square feet of floor space). Make sure these vents are closed and well sealed each winter!

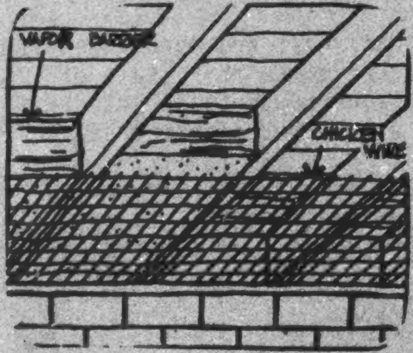
HOW TO DO IT-UNHEATED CRAWL SPACE

As indicated above, this approach should only be taken when the crawl space is moist enough to require ventilation all year round, even with a vapor barrier on the ground.

This job requires the use of batt or blanket insulation, most conveniently the type with the vapor barrier already attached. In detail, the instructions are essentially the same as those for installing batt insulation in the attic, page 67. Appropriate allowance should be made for the inverted situation! It is suggested that these instructions be reviewed before proceeding. Moisture control, while still important, is not so critical as in the attic. This allows for greater flexibility in approach.

A few points of general importance should be summarized:

1) The vapor barrier is to be applied on the warm (top) side of the insulation.



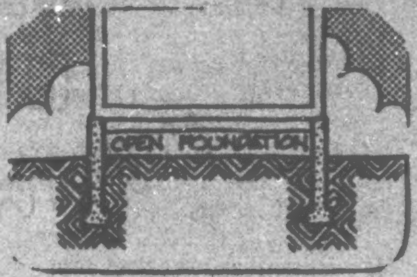
2) The insulation may be held in place by the use of building paper stapled to the joists, by chicken wire, or any other supporting material. If batts are applied separately from the vapor barrier, then they should be held firmly against the barrier, leaving no air space in between.

3) If there are any heating ducts or pipes in the crawl space, insulate them as outlined in Unit 6, pages 25 and 26.

4) Make sure the crawl space is adequately ventilated. You should have at least one square foot of venting for each 500 sq. ft. of floor area.

5) Make sure there is a vapor barrier on the crawl space floor. It should be covered with a 2 inch layer of sand for protection.

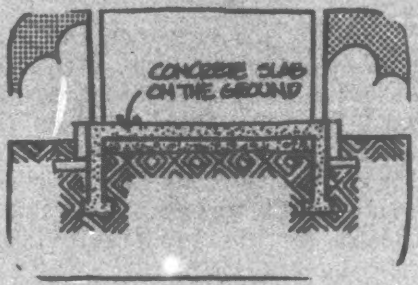
OPEN FOUNDATION



Open foundations should be treated exactly like a ventilated crawl space (above). Additionally, however, the insulation should be protected from the wind, animals, and the like. Heavy building paper or wood applied underneath will do the job.

If the joist space is covered in, the insulation may have to be blown in. Read the comments on page 73, dealing with the blowing full of an attic floor. The open foundation situation is virtually identical, although moisture control here is less critical.

CONCRETE SLAB



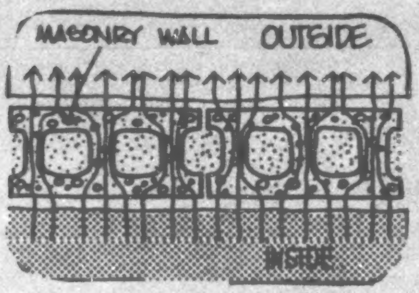
Insulation is applied to the foundation of these basementless houses exactly as you would insulate the outside of a full basement. Refer to page 85 for complete details.

HOW TO INSULATE WALLS

part 3

Re-insulating walls is usually more difficult and more expensive than ceilings or basements. The major exception to this "rule of thumb" is outlined in option A below - if your house falls into this category, you can do the job yourself at a very reasonable cost.

If your house has wood frame walls and is not suitable for option A, then you should consider all the remaining options (B-E) outlined below. All are feasible, though they will be more expensive.



If your house has masonry walls (brick, concrete, stone, etc.) without a wood frame, options A, B, and C may be open to you if you have a continuous air space between two separate layers of masonry. However, concrete block walls should not be insulated by filling the holes with insulation. The block itself will continue to act as a "heat bridge" as illustrated, greatly reducing the effectiveness of the insulation.

Most houses with solid masonry or wood walls which cannot be handled by options A, B, or C, can be handled using options D or E below. In all cases, the descriptions below deal primarily with the more common wood frame wall. Though the detailed requirements will vary, the general approach will remain the same.

NOTE: If there is evidence of existing moisture problems in your wall, make sure that you deal with them first, before adding insulation. Check for leaks where water might enter from the outside or where air might enter from the inside.

A. Loose-Fill Insulation

If your house has a wall space which opens into the attic and if the space is continuous right down to the foundation (check it with a weight on a string), then you can simply pour loose fill insulation into the wall cavity. Make sure you fill each stud space right to the top.

- Some of the spaces are certain to be interrupted by windows or some other obstruction. In such a case, it will be necessary to have the lower portions blown full by a contractor. The cost of this will be minimal when compared to the cost of doing an entire house by this method.

- Since it is not possible, by this method, to install a vapor barrier, you should endeavor to seal all air leaks from the inside of the house into the wall space. Refer to the section on weatherstripping and caulking for more details. You should also be careful not to develop excessive humidity in the house. Finally, further protection can be achieved by painting the inside of the wall with spar varnish, two coats of oil-based paint, or vinyl wall covering.

- Any partial obstructions in the wall space (wires, pipes, etc.) can prevent the insulation from completely filling the cavity. Any "jam-ups" around these barriers can generally be loosed by beating on the inside wall at the appropriate point! In many cases, it is recommended that you go up into the attic a couple of times over the next few months, to check for settling. If there is any, re-fill the spaces to the top again.

B. Blown-in Insulation

If you have hollow or almost hollow wood frame walls that cannot be treated as in A above, then you can have a professional insulation contractor blow-in loose fill insulation. This is the most common means of reinsulating an existing wall. Before you proceed, however, remember that the stud space is likely only 3-1/2 inches thick. If there is already a couple of inches of insulation, the benefits of blowing in more will be small. It might be preferable to invest the time and money on the other parts of the house.

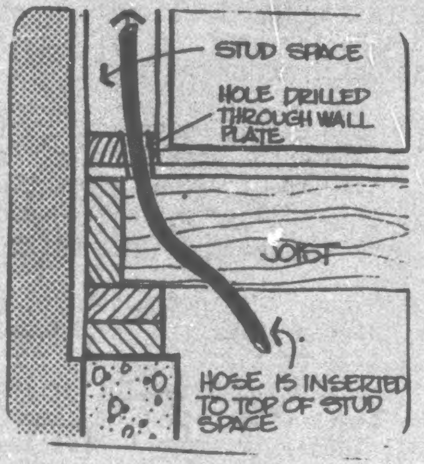
An access hole must be drilled into each stud space in the walls - in some cases two are needed. There are four possible ways of doing this:

1) FROM THE INSIDE WALL: This is to be discouraged in cases where there is an existing vapor barrier, as the drilling will allow air to pass.

2) FROM THE OUTSIDE WALL: Most types of exterior siding can be drilled and then patched with little or no evidence of the work. Brick siding can have single bricks temporarily removed. Make sure the installer patches the individual holes as he moves, rather than leaving them all until the end. Otherwise you may end up with several rain holes in your wall when that flash storm hits!

3) FROM THE BASEMENT: This can be the easiest approach. A long tube is inserted to the top of the stud space, and then withdrawn as the space fills. The pressure packs the material from the top down.

4) FROM THE ATTIC: In a similar manner, a hole can be drilled in the top plate of the wall. A hose is then inserted from the attic, down the wall. As the space fills, it is withdrawn.


STUD SPACE
HOLE DRILLED THROUGH WALL PLATE
JOIST
HOSE IS INSERTED TO TOP OF STUD SPACE

All spaces in the wall need to be filled - fire breaks, cross braces, and other obstructions in the wall cavity need to be allowed for.

The relative merits of the different loose fill insulations are outlined on page 52. In addition to the information outlined there, it is worth to note that cellulose fiber in a blow-in application will more readily fill irregular spaces than the other materials. Carefully choose the insulation to be used in consulation with the contractor.

When you have settled on the material, figure out how much should be used. The bags of insulation will indicate on them how many square feet each should fill to give the required R-value. Make sure the information used is for wall applications. Knowing the size of the wall to be filled, you and the contractor should agree on the number of bags to be used - and write it into the contract. Only a small variation from that target is acceptable. If he uses too little, you will find that the insulation settles, leaving gaps in the wall. If he uses too much, some of the insulation may be escaping from the wall into a floor space or some other area where it is not needed - a big waste! So make-sure the right amount is used.

If there is no vapor barrier, it may still be possible to proceed, since the insulation itself helps restrict air flow. Cellulose fiber blown in at high density is particularly effective in this regard. At the same time, an active program to seal all air leaks into the wall and cut down on humidity sources should be undertaken. A coat or two of low-permeability paint (oil based or spar varnish) also may be applied to the inside wall.

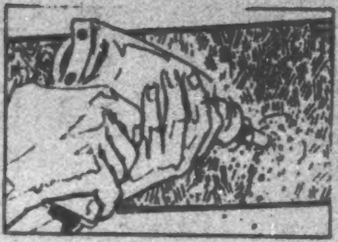
C. Foamed-In-Place Insulation

The cavity in wood frame houses and in some masonry walls (i.e. stone, brick, etc.), can be filled with foamed-in-place insulation. The material is injected into the cavity as a semi-liquid foam, which quickly solidifies to give a solid insulation material.

The polyurethane foams are not recommended for this application as they are highly flammable and fatally toxic.

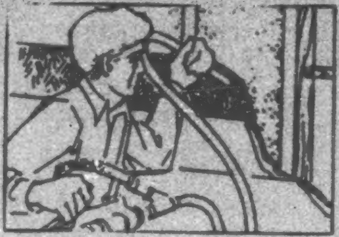
Urea formaldehyde foam may be an acceptable way to treat older walls, however, a number of formulations are subject to shrinkage, degradation and moisture problems. The rate of shrinkage varies somewhat from one manufacturer but some is evident in even the best formulas. This shrinkage varies from 1.5% to as much as 6%. Shrinkage as high as 12% has been reported on poor insulation jobs. RAPCO foam of Rapperawill Corp. recently has reported that their products' shrinkage factor is less than 1%. The effective "R" value is therefore approximately 4.5 per inch for a standard 3-1/2 inch stud space. Currently U.F. foam may only be applied to walls with no insulation whatever. U.F. foam should never be applied to attic or floors. When installed in a horizontal position, the shrinkage problem increases and does the odor of the chemicals. U.F. foam should be installed by a reputable contractor which has work in the area. Before hiring, ask to see prior insulation installations.

Installing U.F. foam takes us less than a day for an average home. It is applied through the exterior walls. Here's how.



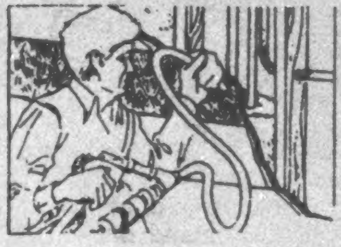
Access holes are drilled through sheathing for each and every wall cavity. (Siding is removed by request.)

(Celsius)



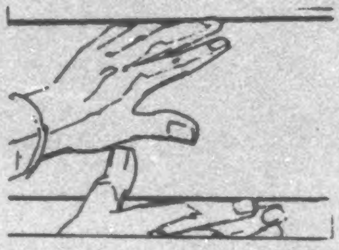
Gun hose is inserted deep into the cavity and foam is pumped in at the consistency of shaving cream.

(Celsius)



Entire cavity is filled with foam flowing around pipes and electrical outlets and filling every crevice.

(Celsius)



In a few seconds foam sets to the consistency of sponge cake. Siding is replaced or the holes are plugged with a wooden plug (for wood frame home) or a plastic plug if aluminum siding has been drilled. (Aluminum siding can be removed.)

(Celsius)

D. Wall Renovation

If your plans permit extensive renovation, you have two options:

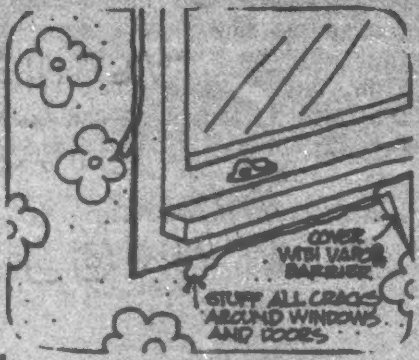
1) REBUILD THE EXISTING WALL: With wood frame houses only, you may remove the wall board or plaster already in place and reinsulate the wall.- While you are at it, you may want to attach 1 x 2" or 2 x 2" strips to the stud edges to allow for more insulation in the wall cavity.

2) BUILD A NEW WALL INSIDE THE OLD: With both wood frame and masonry walls, you may build a new wall inside the existing one, and then insulate it. This approach is only possible if there is no vapor barrier in the existing wall, or, if there is, its effectiveness can be reduced (by cutting) or add a more effective air vapor barrier.

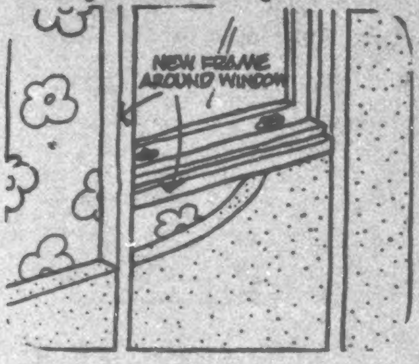
IN BOTH CASES: Follow the relevant portions of the instructions on reinsulating a basement from the inside (page 79). A few additional points should be noted, however:

- When installing a separate polyethylene vapor barrier, unroll the sheet across the entire wall area, including window and door openings. These can be cut out later.

- Make sure the insulation and barrier extend to behind any pipes, electrical boxes, etc., such that these obstructions are on the warm side of the insulation. This may be difficult when building new inside walls. Electrical boxes may be moved into the new wall by a qualified tradesman or they might simply be inactivated and left on the cold side. Pipes are more difficult. If there are any in your existing wall (follow them up from the basement and down from the bathroom and kitchen) they could freeze and burst if left outside the insulation. Try to somehow get behind them, rather than in front. If this isn't possible, then don't insulate using the new wall approach.


COVER WITH VAPOR BARRIER
STUFF ALL CRACKS AROUND WINDOWS AND DOORS

- If you are rebuilding the existing wall, be sure to stuff all cracks around doors or windows with insulation or oakum (a material used specifically as a filler, available from your building materials supplier).

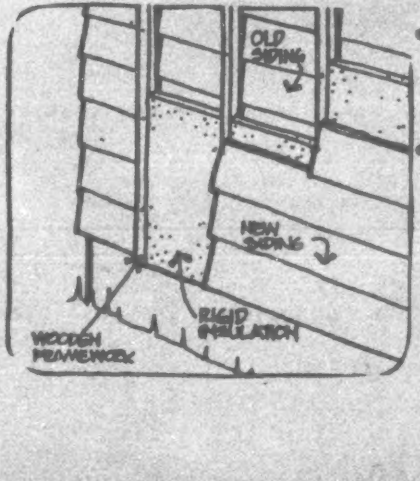

NEW FRAME AROUND WINDOW

- For non-standard stud spaces, cut the insulation (if the batt type is used) and any attached vapor barrier to about an inch wider than the space to be filled.

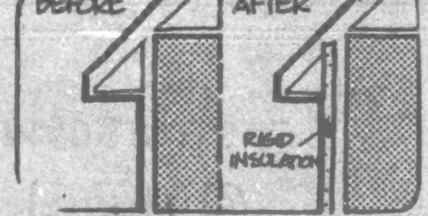
E. Insulate Outside

If you are installing new siding on the house in any case, it may be worthwhile to install polystyrene over the old siding, but under the new. A few points to keep in mind:

- A wooden framework should be built over the entire outside wall to position the insulation and support the new siding.
- No vapor barrier should be added.


OLD SIDING
NEW SIDING
RIGID INSULATION
WOODEN FRAMEWORK

- Unless the old siding supplies a good surface for glueing, the polystyrene should be nailed in place.
- The insulation should be extended right to the top of the wall, which


BEFORE
AFTER
RIGID INSULATION

may require going up into the eaves, as illustrated.

- If this does not prevent water from getting in between the insulation and the siding, then you must add "flashing" at the top of the insulation for this precise purpose. Consult with your building materials supplier.

Compare your needs with the various available options, and choose the one that seems most suitable. In a majority of cases, that will be blowing in insulation. The investment will be fairly high, but remember that it will be recovered in time. After that, it is money in the bank for you - and you have a better house for it!

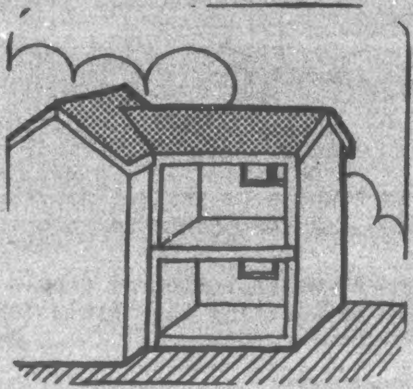
part 4

MISCELLANEOUS SPACES

Everyone knows that warm air rises. But heat also radiates in all directions. So walls and floors must be insulated where they adjoin onto an unheated space.

This section deals with four special cases:

A. UNHEATED GARAGE
B. COLD CELLAR
C. OVERHANG
D. ENCLOSED PORCH



A. Unheated Garage

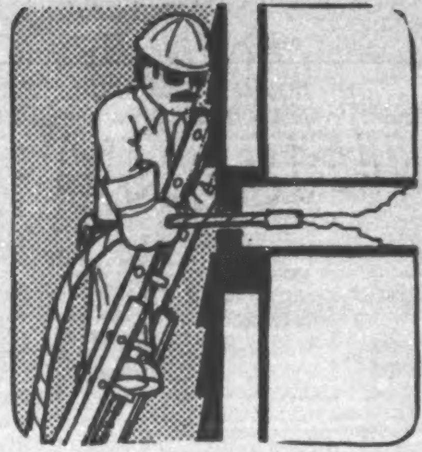
The walls and ceiling adjoining the house must be insulated in the locations illustrated.

THE WALLS
Refer to Part III for instructions regarding wall insulation if the garage is above ground; refer to Part II if it is below.

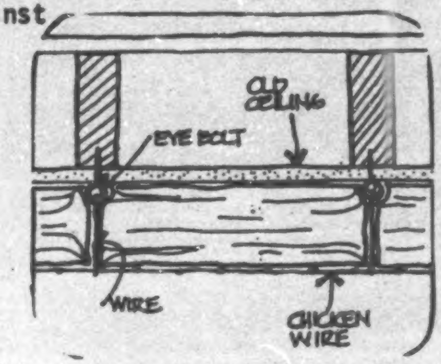
THE CEILING

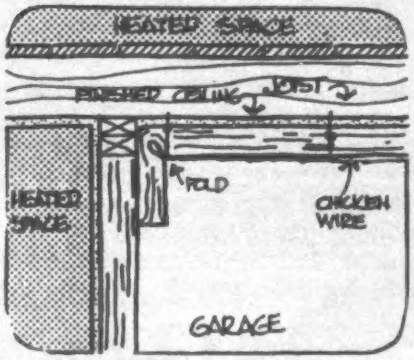
- If there are open joists showing, proceed as outlined for ventilated crawl spaces in Part II.

- If, however, the ceiling is finished, two approaches are possible.



- A contractor can blow the ceiling full of insulation. Read the comments on page 73 relating to the blowing of a covered attic floor. In the case of a garage ceiling, moisture is less critical, but otherwise the procedure is the same. Any holes cut in the ceiling should be carefully re-sealed to prevent fume leakage into the rooms above.
- Batt type insulation may be slung from the ceiling using chicken wire to hold it firmly in place against the ceiling. No other framing support is required. If no vapor barrier is present in the existing garage ceiling, one should be added on the upper (warm side). Continuous 6-mil polyethylene sheeting is recommended over the less effective barriers attached to some batts and blankets.





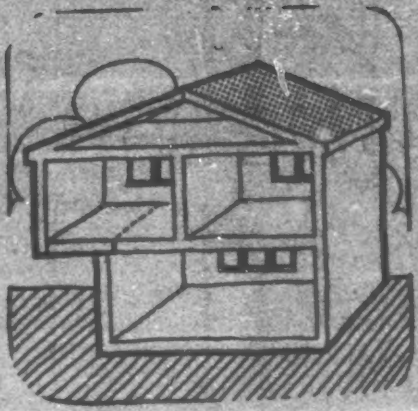
This insulation method is simple, but can be leaky if installed sloppily. In order to ensure a tight, snug fit, it is recommended that eye bolts be screwed into the ceiling at regular, "batt sized" intervals. Wires may then be attached to support the chicken wire, as shown. Furthermore, where the insulation meets the heated wall, it should be folded down slightly.

B. Cold Cellar

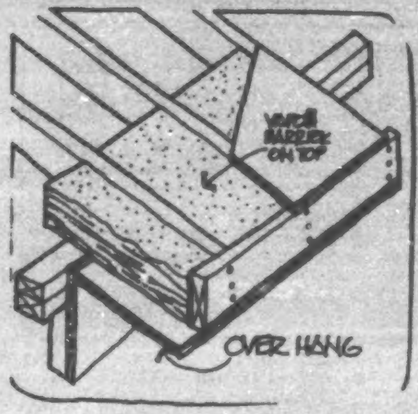
- The cold cellar walls, door, and ceiling should be insulated. Apart from saving heat, your cold cellar will be colder.
- Treat the walls as outlined in Part II, page 78.
- Treat the ceiling as outlined in the garage section above.

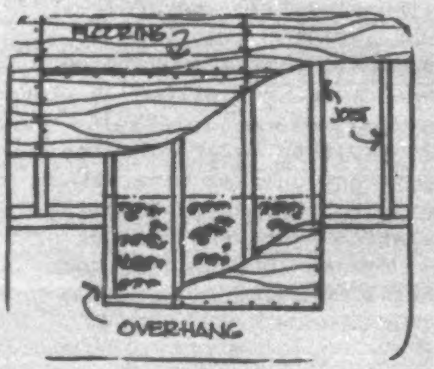
C. Overhang

The floor of any overhang should be tightly filled with insulation.



- If the overhang is on the first floor, this task should be easily accomplished from the basement by stuffing in some batt insulation to fill the space. The vapor barrier should face up to the warm side.



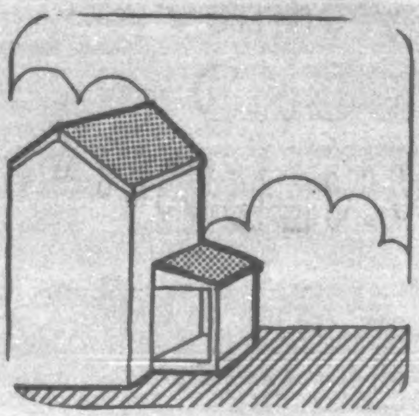


- If the overhang is between the first and second floor, the problem is more difficult. If you can easily lift the floorboards or remove the outside surface, then fill the space with batt insulation, extending it into the main part of the house a few inches.

If that can't be done, it is probably not worth going further. If a contractor is working on your house anyway, ask him if he could blow the overhang space full. The major problem will likely be the fact that overhang space is continuous with the rest of the floor as shown. A good operator can, however, blow just the right part of the space, without filling the entire floor!

D. Enclosed Porch

The wall between the heated interior and an unheated, enclosed porch or summer kitchen should be treated exactly like an outside wall. Refer to Part III of this unit for details.



Condensation Problems In Your Home: Prevention And Solution

By
L.O. Anderson and G.E. Sherwood

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INTRODUCTION

PURPOSE AND SCOPE

This unit is intended to serve as a guide for homeowners-not only as a means of preventing condensation problems, but also to better understand their cause. It contains information and recommendations for correct methods of installing vapor barriers, thermal insulation, and inlet and outlet ventilators in new homes. Methods which can be used to correct moisture problems in existing houses are also included.

The majority of the suggestions and recommendations are applicable to the typical wood-frame house. This unit illustrates use of typical materials and does not imply that other materials of equal quality and arrangement cannot be used successfully. Principles involved and procedures used to minimize the problem are equally applicable to commercial and farm buildings where conditions are similar to those in a home.

Because wood is so important a part of American homes, the research program of the Forest Products Laboratory has long included studies on proper use of wood-based materials. Information here is based on research by Laboratory and other scientists and engineers as well as experiences provided by the building industries and homeowners.

BACKGROUND

In the cooler regions of the United States-notably where the January temperature averages 35°F. or lower-the first signs of spring may include dark stains on house siding and peeling paint. These often indicate a cold weather condensation problem. The formation of icicles or an ice dam at the cornice of a house after a heavy snowfall indicates another type of moisture problem that requires correction.

Condensation can be described as the change in moisture from a vapor to a liquid. In homes not properly protected, condensation caused by high humidities often results in excessive maintenance costs. Water vapor within the house, when unrestricted, can move through the wall or ceiling during the heating season to some cold surface where it condenses, collecting generally in the form of ice or frost. During warm periods the frost melts. When conditions are severe, the water from melting ice in unvented attics may drip to the ceiling below and cause damage to the interior finish. Moisture can also soak into the roof sheathing or rafters and set up conditions which could lead to decay. In walls, water from melting frost may run out between the siding laps and cause staining or soak into the siding and cause paint blistering and peeling.

Wood and wood-base materials used for sheathing and panel siding may swell from this added moisture and result in bowing, cupping, or buckling. Thermal insulation also becomes wet and provides less resistance to heat loss. Efflorescence may occur on brick or stone of an exterior wall because of such condensation.

The cost of heat losses, painting and redecorating, and excessive maintenance and repair caused by cold weather condensation can be easily reduced or eliminated when proper construction details are used.

Changes in design, materials, and construction methods since the mid-thirties have resulted in houses that are easier to heat and more comfortable, but these changes have accentuated the potential for condensation problems. New types of weatherstripping, storm sash, and sheet material for sheathing in new houses provide tight air-resistant construction which restricts the escape of moisture generated in the house. Newer houses are also generally smaller and have lower ceilings resulting in less atmosphere to hold moisture.

Estimates have been made that a typical family of four converts 3 gallons of water into water vapor per day. Unless excess water vapor is properly removed in some way (ventilation usually), it will either increase the humidity or condense on cold surfaces such as window glass. More serious, however, it can move in or through the construction, often condensing within the wall, roof, or floor cavities. Heating systems equipped with winter air-conditioning systems also increase the humidity.

Most new houses have from 2 to 3-1/2 inches of insulation in the walls and 6 or more inches in the ceilings. Unfortunately, the more efficient the insulation is in retarding heat transfer, the colder the outer surfaces become and unless moisture is restricted from entering the wall or ceiling, the greater the potential for moisture condensation. Moisture migrates toward cold surfaces and will condense or form as frost or ice on these surfaces.

Inexpensive methods of preventing condensation problems are available. They mainly involve the proper use of vapor barriers and good ventilating practices. Naturally it is simpler, more inexpensive, and more effective to employ these during the construction of a house than to add them to existing homes.

Condensation Factors

Condensation will take place anytime the temperature drops below dewpoint (100 percent saturation of the air with water vapor at a given temperature). Commonly, under such conditions some surface accessible to the moisture in the air is cooler than the dewpoint and the moisture condenses on that surface.

CONCEALED CONDENSATION

During cold weather, visible condensation is usually first noticed on window glass but may also be discovered on cold surfaces of closet and unheated bedroom walls and ceilings. Condensation might also be visible in attic spaces on rafters or roof boards near the cold cornice area or form as frost. Such condensation or melting frost can result in excessive maintenance, such as the need for refinishing of window sash and trim, or even decay. Water from melting frost in the attic can also damage ceilings below.

Another area where visible condensation can occur is in crawl spaces under occupied rooms. This area usually differs from those on the interior of the house and in the attic because the source of the moisture is usually from the soil or from warm moisture-laden air which enters through foundation ventilators. Moisture vapor then condenses on the cooler surfaces in the crawl space. Such conditions often occur during warm periods in late spring.

An increase in relative humidity of the inside atmosphere increases the potential for condensation on inside surfaces. For example, when inside temperature is 70°F., surface condensation will occur on a single glass window when outside temperature falls to -10°F. and inside relative humidity is 10 percent. When inside relative humidity is 20 percent, condensation can occur on the single glass when outside temperature only falls to about +7°F. When a storm window is added or insulated glass is used, surface condensation will not occur until the relative humidity has reached 38 percent when the outdoor temperature is -10°F. The above conditions apply only where storm windows are tight and there is good circulation of air on the inside surface of the window. Where drapes or shades restrict circulation of air, storm windows are not tight, or lower temperatures are maintained in such areas as bedrooms, condensation will occur at a higher outside temperature.

VISIBLE CONDENSATION

Condensation in concealed areas, such as wall spaces, often is first noticed by stains on the siding or by paint peeling. Water vapor moving through permeable walls and ceilings is normally responsibility for such damage. Water vapor also escapes from houses by constant outleakage through cracks and crevices, around doors and windows, and by ventilation, but this moisture-vapor loss is usually insufficient to eliminate condensation problems.

MOISTURE SOURCES

INTERIOR. -Moisture, which is produced in or which enters a home, changes the relative humidity of the interior atmosphere. Ordinary household functions which generate a good share of the total amount of water vapor include dish-washing, cooking, bathing, and laundry work, to say nothing of human respiration and evaporation from plants. Houses may also be equipped with central winter air conditioners or room humidifiers. Still another source of moisture may be from unvented or poorly vented clothes dryers. Several sources and their effect in adding water vapor to the interior of the house are:

	PINTS OF WATER
Plants	-1.7 for each plant in 24 hours
Showers	-0.5 for each shower and -0.1 for each bath
Floor mopping	-2.9 per 100 square feet, each washing
Kettles and cooking	-5.5 per day
Clothes (washing, steam, ironing, drying)	-29.4 per week

CRAWL SPACE. -Water vapor from the soil of crawl-space houses does not normally affect the occupied areas. However, without good construction practices or proper precautions it can be a factor in causing problems in exterior walls over the area as well as in the crawl space itself. It is another source of moisture that must be considered in providing protection.

WATER FROM CONSTRUCTION. -People moving into a newly constructed house in the fall or early winter sometimes experience temporary moisture problems. Surface condensation on windows, damp areas on cold closet walls where air movement is restricted, and even stained siding-all indicate an excessive amount of moisture. Such conditions can often be traced to water used in the construction of a house.

Basement floors, concrete walls, and plastered walls and ceilings require a tremendous amount of water during their construction. While much of this water has evaporated from the surface after a month or so, the addition of heat aids in driving off more moisture as these elements reach moisture equilbrium with the surrounding atmosphere. This moisture creates higher than normal humidities, and the increased amount of vapor drives vapor toward colder areas in attics or in the walls.

A concrete floor in the basement of a small home contains more than 240 gallons of water when it is poured. The concrete basement walls of this same home contain over 480 gallons of water. If the house is plastered, over 300 gallons of water are used. Thus, it is often a common occurrence to have some moisture problems when a house is just completed. These are normally corrected after the first heating season. However, several methods may be used to reduce this excessive moisture. Perhaps the simplest is to heat and ventilate a new house so that excessive moisture is dissipated outdoors before the occupants move in.

MISCELLANEOUS. -There are other sources of moisture, often unsuspected, which could be the cause of condensation problems. One such source can be a gas-fired furnace. It is desirable to maintain flue-gas temperatures within the recommended limits throughout the appliance, in the flue, the connecting vent, and other areas; otherwise excessive condensation problems can result. If all sources of excessive moisture have been exhausted in determining the reasons for a condensation problem, it is well to have the heating unit examined by a competent heating engineer.

There is a distinct relationship in all homes between indoor relative humidity and outdoor temperature. The humidity is generally high indoors when outdoor temperatures are high and decreases as outdoor temperatures drop. In an exceptionally tight modern house where moisture buildup may be a problem, outside air should be introduced into the cold air return ducts to reduce relative humidity.

VAPOR BARRIERS

Many materials used as interior coverings for exposed walls and ceiling, such as plaster, dry wall, wood paneling, and plywood, permit water vapor to pass slowly through them during cold weather. Temperatures of the sheathing or siding on the outside of the wall are often low enough to cause condensation of water vapor within the cavities of a framed wall. When the relative humidity within the house at the surface of an unprotected wall is greater than that within the wall, water vapor will migrate through the plaster or other finish into the stud space; there it will condense if it comes in contact with surfaces colder than its dewpoint temperature. Vapor barriers are used to resist this movement of water vapor or moisture in various areas of the house.

The amount of condensation that can develop within a wall depends upon (a) the resistance of the intervening materials to vapor transfusion, (b) differences in vapor pressure, and (c) time. Plastered walls or ordinary dry walls have little resistance to vapor movement. However, when the surfaces are painted with oil-base paint, the resistance is increased. High indoor temperatures and relative humidities result in high indoor vapor pressures. Low outdoor vapor pressures always exist at low temperatures. Thus, a combination of high inside temperatures and humidities and low outside temperatures will normally result in vapor movement into the wall if no vapor barrier is present. Long periods of severe weather will result in condensation problems. Though fewer homes are affected by condensation in mild winter weather, many problems have been reported. Where information is available, it appears that the minimum relative humidities in the affected homes are 35 percent or higher.

Vapor barrier requirements are sometimes satisfied by one of the materials used in a construction. In addition to integral vapor barriers which are a part of many types of insulation, such materials as plastic-faced hardboard and similar interior coverings may have sufficient resistance when the permeability of the exterior construction is not too low. The permeability of the surface to such vapor movement is usually expressed in "perms," which are grains of water vapor passing through a square foot of material per hour per inch of mercury difference in vapor pressure. A material with a low perm value (1.0 or less) is a barrier, while one with a high perm value (greater than 1.0) is a "breather."

The perm value of the cold side materials should be several times greater than those on the warm side. A ratio of 1 to 5 or greater from inside to outside is sometimes used as a rule of thumb in selecting materials and finish. When this is not possible because of virtually impermeable outside construction (such as build-up roof or resistant exterior wall membranes), research has indicated the need to ventilate the space between the insulation and the outer covering. However, few specific data are available on ventilation requirements for walls.

AREAS OF VAPOR BARRIER USE. -Vapor barriers are used in three general areas of the house to minimize condensation or moisture problems:

WALLS, CEILINGS, FLOORS. -Vapor barriers used on the warm side of all exposed walls, ceilings, and floors greatly reduce movement of water vapor to colder surfaces where harmful condensation can occur. For such uses it is good practice to select materials with perm values of 0.25 or less. Such vapor barriers can be a part of the insulation or a separate film. Commonly used materials are (a) asphalt-coated or laminated papers, (b) kraft-backed aluminum foil, and (c) plastic films such as polyethylene, and others. Foil-backed gypsum board and various coatings also serve as vapor barriers. Oil-base or aluminum paints, or similar coatings are often used in houses which did not have other vapor barriers installed during their construction.

CONCRETE SLABS. -Vapor barriers under concrete slabs resist the movement of moisture through the concrete and into living areas. Such vapor barriers should normally have a maximum perm value of 0.50. But the material must also have adequate resistance to the hazards of pouring concrete. Thus, a satisfactory material must be heavy enough to withstand such damage and at the same time have an adequate perm value. Heavy asphalt laminated papers, papers with laminated films, roll roofing, heavy films such as polyethylene, and other materials are commonly used as vapor barriers under slabs.

CRAWL SPACE COVERS. -Vapor barriers in crawl spaces prevent ground moisture from moving up and condensing on wood members. A perm value of 1.0 or less is considered satisfactory for such use. Asphalt laminated paper, polyethylene, and similar materials are commonly used. Strength and resistance of crawl space covering to mechanical damage can be lower than that for vapor barriers used under concrete slabs.

EXTERIOR MATERIALS

In new constructions where low permeance vapor barriers are properly installed, most commercially available sheathing and siding materials and coatings can be used without creating condensation problems. However, in structures without vapor barriers, a low permeance material or coating on the outside can retard the escape of moisture which has been forced into the wall from the inside. An alternative finish for such situation is a penetrating stain, which does not form a coating on the wood surface and so does not retard the movement of moisture. Penetrating stains are very durable and easily refinished because they do not fail by blistering or peeling. Where the older home has a paint peeling problem due to condensation, the siding should be painted with white latex paint, which is very porous, and then spot-painted annually whereever peeling occurs. White paint is recommended because it does not fade and retains a good exterior appearance between yearly touchups.

THERMAL INSULATION

Thermal insulation has a major influence on the need for vapor barriers. The inner face of the wall sheathing in an insulated wall, for example, is colder than the sheathing face in an uninsulated wall and consequently has a greater attraction to moisture. Thus there is greater need for a vapor barrier in an insulated wall than in an uninsulated wall.

VENTILATION

Ventilation used in proper amounts and locations is a recognized means of controlling condensation in buildings. Inlet and outlet ventilators in attic spaces, ventilation of rafter spaces in flat roofs and crawl space ventilation aid in preventing accumulation of condensation in these areas. By introducing fresh air into living quarters during the winter, some humid air is forced out of the house while the incoming air has a low water vapor content. Well installed vapor barriers may increase the need for ventilation in living quarters because little of the moisture generated can get out and may build up.

The use of both inlet and outlet ventilators in attic spaces aids in keeping the air moving and preventing the accumulation of frost or condensation on roof boards in cold areas. "Dead" air pockets in the attic can normally be prevented by good distribution of inlet ventilators in the soffit areas. However, there is still a need for vapor barriers in the ceiling; ventilation alone, when insulation is used, does not prevent condensation problems. A good vapor barrier is especially needed under the insulation in a flat roof where ventilation can normally be provided only in the overhang.

Crawl space moisture, which results in high moisture content of the wood members, can be almost entirely eliminated by a vapor barrier over the soil. When such protection is used, the need for ventilation is usually reduced to only 10 percent of that required when a soil cover is not present.

During warm damp periods in early summer, moisture often condenses on basement walls or around the perimeter of the floor in concrete slab houses. Soil temperatures in the northern part of the United States remain quite low until summer, and surface temperatures of the floor or wall are often below dewpoint. When the concrete reaches normal temperature and the atmosphere changes, such problems are normally reduced or eliminated.

Recommendations

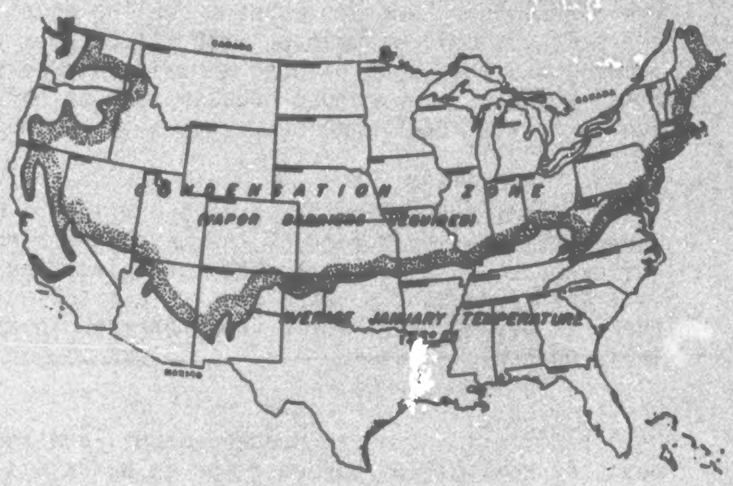


Figure 3.—Winter condensation problems occur where the average temperature for January is 35° F. or lower.

CONDENSATION ZONES

The control of condensation through the use of vapor barriers and ventilation should be practiced regardless of the amount of insulation used. Normally, winter condensation problems occur in those parts of the United States where the average January temperature is 35°F. or lower. Figure 3 illustrates this condensation zone. The northern half of the condensation zone has a lower average winter temperature, and of course, more severe conditions than the southern portion. Areas outside this zone, such as the southeast and west coastal areas and the southern states, seldom have condensation problems. Vapor barriers should be installed at the time of construction in all new houses built within the condensation zone outlined in Figure 3 and proper ventilation procedures should be followed. These will insure control over normal condensation problems.

LOCATION OF VAPOR BARRIERS

A good general rule to keep in mind when installing vapor barriers in a house is as follows: "Place the vapor barrier as close as possible to the interior or warm surface of all exposed walls, ceilings, and floors." This normally means placing the vapor barrier (separately or as a part of the insulation) on (a) the inside edge of the studs just under the rock lath or dry wall finish, (b) on the under side of the ceiling joists of a one-story house or the second floor ceiling joists of a two-story house, and (c) between the subfloor and finish floor (or just under the subfloor of a house with an unheated crawl space in addition to the one placed on the ground). The insulation, of course, is normally placed between studs or other frame members on the outside of the vapor barrier. The exception is the insulation used on concrete floor slabs where a barrier is used under the insulation to protect it from ground moisture.

Placement of vapor barriers and insulation in one-story houses are shown in Figure 4 (flat roof and concrete floor slab) and Figure 5 (pitched roof and crawl space). Figure 6 shows barriers and insulation in a 1-1/2-story house with full basement. Figure 7 depicts a two-story house with full basement. Other combinations of slabs, crawl spaces, and basements in houses with 1, 1-1/2, or 2 stories, should follow the same general recommendations. Detailed descriptions in the use of vapor barriers will be covered in the following sections.

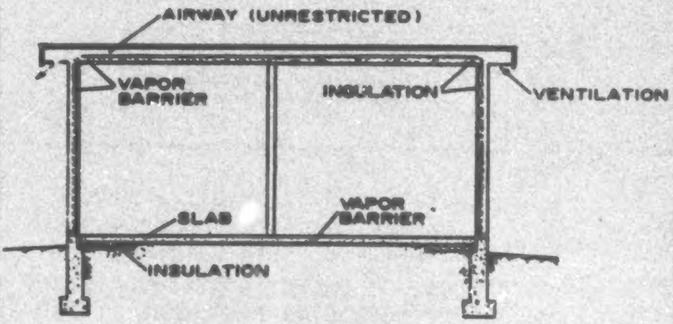


Figure 4.—Location of vapor barriers and insulation in concrete slab and flatdeck roof.
[illegible]

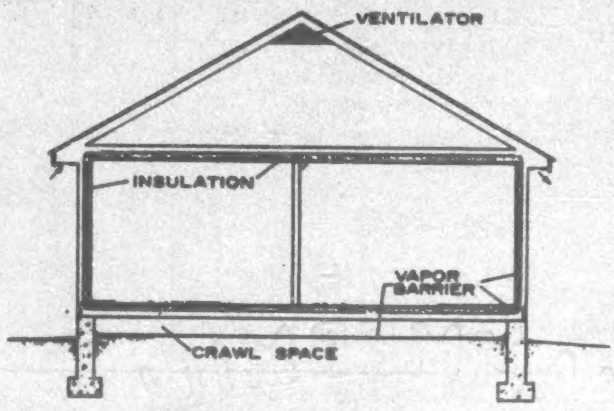


Figure 5.—Location of vapor barriers and insulation in crawl space of another one-story house.
[illegible]

CONCRETE SLABS

A house constructed over a concrete slab must be protected from soil moisture which may enter the slab. Protection is normally provided by a vapor barrier, which completely isolates the concrete and perimeter insulation from the soil. Thermal insulation of some type is required around the house perimeter in the colder climates, not only to reduce heat loss but also to minimize condensation on the colder concrete surfaces. Some

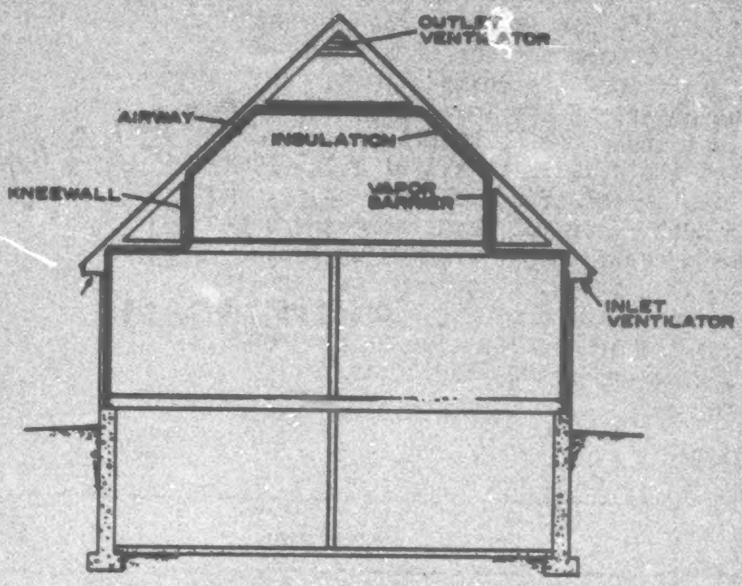


Figure 6.—Location of vapor barriers and insulation in 1-1/2-story house with basement.

type of rigid insulation impervious to moisture absorption should be used. Expanded plastic insulation such as polystyrene is commonly used.

One method of installing this insulation is shown in Figure 8. Another method consists of placing it vertically along the inside of the foundation wall. Both methods require insulation at the slab notch of the wall. If the insulation is placed vertically, it should extend a minimum of 12 inches below the outside finish grade. In the colder climates, a minimum 24-inch width or depth should be used.

In late spring or early summer, periods of high humidity may cause surface condensation on exposed concrete slabs or on coverings such as resilient tile before the concrete has reached normal temperatures. A fully insulated slab or a wood floor installed over wood furring strips minimizes if not eliminates such problems.

Because the vapor barriers slow the curing process of the concrete, final steel troweling of the surface is somewhat delayed. Do not punch holes through the barrier to hasten the curing process as this will destory its effectiveness!

CRAWL SPACES

Enclosed crawl spaces requires some protection to prevent problems caused by excessive soil moisture. In an unheated crawl space this usually consists of a vapor barrier over the soil, together

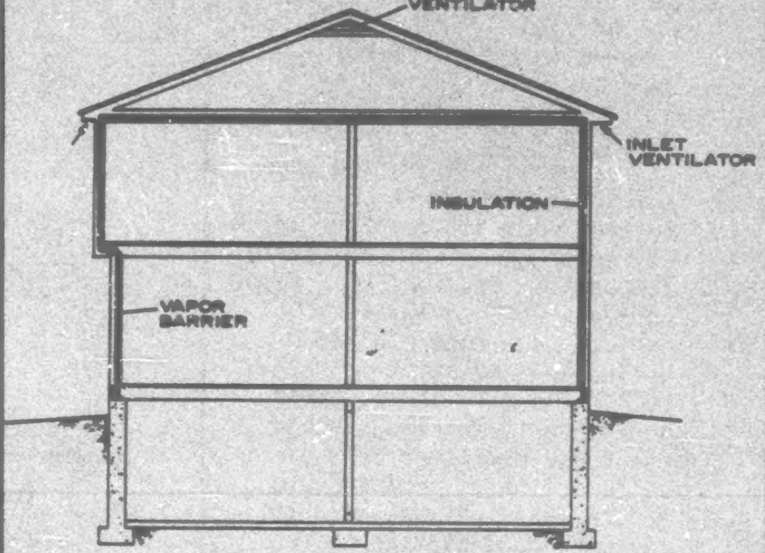


Figure 7.—Location of vapor barriers and insulation in full two-story house with basement.

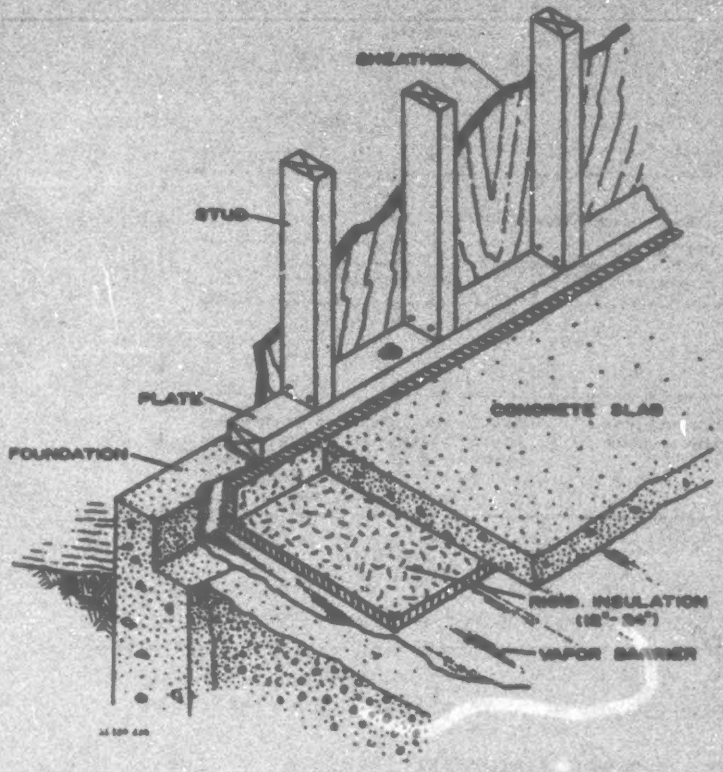

SHEATHING
STUD
PLATE
FOUNDATION
CONCRETE SLAB
RIGID INSULATION
(12"-24")
VAPOR BARRIER

Figure 8.—Installation of vapor barrier under concrete slab.

with foundation ventilators. In heated crawl spaces, a vapor barrier and perimeter insulation is used but foundation ventilators are eliminated.

UNHEATED CRAWL SPACE. -To provide complete protection from condensation problems, the conventional unheated crawl space usually contains (a) foundation ventilators, (b) a ground cover (vapor barrier), and (c) thermal insulation between the floor joists. Foundation ventilators are normally located near the top of the masonry wall. In concrete block foundations, the ventilator is often made in a size to replace a full block, Figure 9.

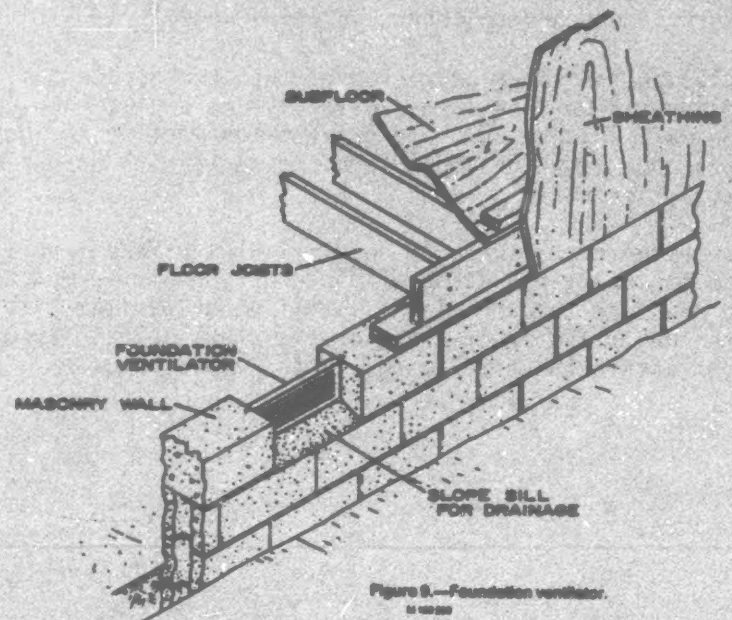

SUBFLOOR
SHEATHING
FLOOR JOISTS
FOUNDATION VENTILATOR
MASONRY WALL
SLOPE SILL FOR DRAINAGE

Figure 9.—Foundation ventilator.

Table 1.—Crawl-space ventilation

Crawl space	Ratio of total net ventilating area to floor area[1]	Minimum number of ventilators[2]
Without vapor barrier	1/150	4
With vapor barrier	1/1500	2

[1] The actual area of the ventilators depends on the type of louvers and size of screen used—see table 2.

[2] Foundation ventilators should be distributed around foundation to provide best air movement. When two are used, place one toward the side of prevailing wind and the other on opposite side.

The amount of ventilation required for a crawl space is based on the total area of the house in square feet and the presence of a vapor barrier soil cover. Table 1 lists the recommended minimun net ventilating areas for crawl space with or without vapor barriers.

The flow of air through a ventilator is restricted by the presence of screening and by the louvers. This reduction varies with the size of the screening or mesh and by the type of louvers used. Louvers are sloped about 45° to shed rain when used in a vertical position. Table 2 outlines the amount by which the total calculated net area of the ventilators must be increased to compensate for screens and thickness of the louvers.

In placing the vapor barrier over the crawl-space soil, adjoining edges should be lapped slightly and ends turned up on the foundation wall (Figure 10). To prevent movement of the barrier, it is good practice to weight down laps and edges with bricks or other small masonry sections.

An unheated crawl space in cold climates offers insufficient protection to supply and disposal pipes during winter months. It is common practice to use a large vitrified or similar tile to enclose the water and sewer lines in the crawl space. Insulation is then placed within the tile to the floor level.

Table 2.—Ventilating area increase required if louvers and screening are used in crawl spaces and attics

Obstructions in ventilators—louvers and screens[1]	To determine total area of ventilators, multiply required net area in square feet by:[2]
1/4-inch-mesh hardware cloth	1
1/8-inch-mesh screen	1-1/4
No. 16-mesh insect screen (with or without plain metal louvers)	2
Wood louvers and 1/4-inch-mesh hardware cloth[3]	2
Wood louvers and 1/8-inch-mesh screen[3]	2-1/4
Wood louvers and No. 16-mesh insect screen[3]	3

[1] In crawl-space ventilators, screen openings should not be larger than 1/4 inch; in attic spaces no larger than 1/8 inch.

[2] Net area for attics determined by ratios in figures 22, 23, and 24.

[3] If metal louvers have drip edges that reduce the opening, use same ratio as shown for wood louvers.

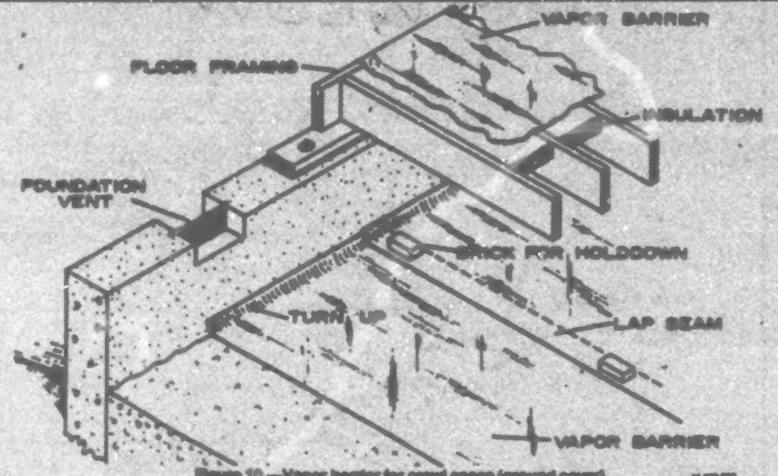


Figure 10.—Vapor barrier for crawl space (ground cover).

Insulating batts, with an attached vapor barrier, are normally located between the floor joists. They can be fastened by placing the tabs over the edge of the joists before the subfloor is installed when the cover (vapor barrier) is strong enough to support the insulation batt (Figure 10). However, there is often a hazard of the insulation becoming wet before the subfloor is installed and the house enclosed. Thus, it is advisable to use one of the following alternate methods:

Friction-type batt insulation is made to fit tightly between joists and may be installed from the crawl space as shown in Figure 11, A. It is good practice to use small "dabs" of mastic adhesive to insure that it remains in place against the subfloor. When the vapor barrier is not a part of the insulation, a separate film should be placed between the subfloor and the finish floor.

When standard batt or blanket insulation containing an integral vapor barrier is not installed from above before the subfloor is applied, several alternate methods can be used. If the vapor barrier and enclosing paper wrap is strong enough it can be installed with a mastic adhesive in the same manner as the friction type (Figure 11, A). Floor insulation may also be supported by a wire mesh held in place by wood strips (Figure 11, B). A third method used to install the insulation from the crawl space consists of using small wood strips applied across the joist space (Figure 11, C). The strips are cut slightly longer than the width of the space and sprung in place so that they bear against the bottom of the insulation.

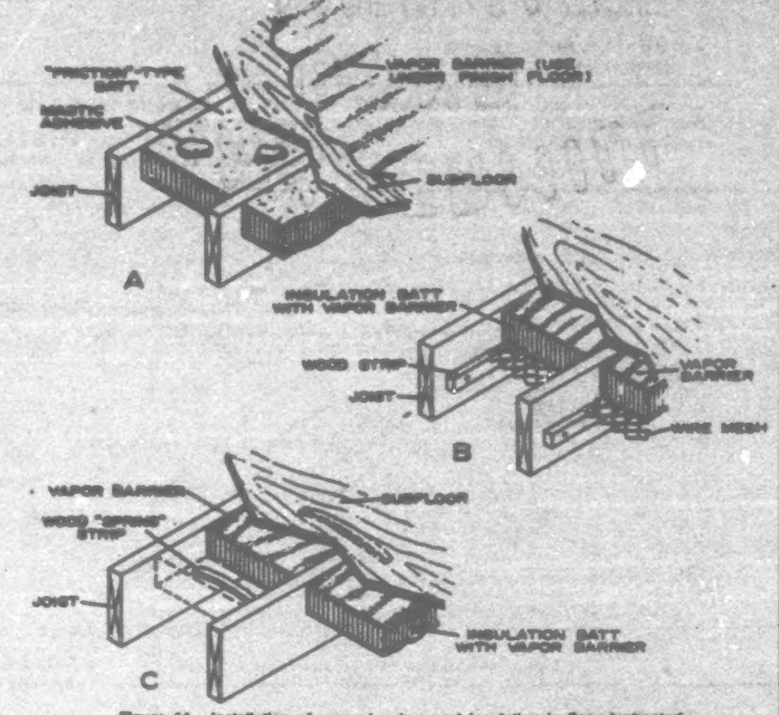

"FRICTION"-TYPE BATT
MASTIC ADHESIVE
JOIST
VAPOR BARRIER (USE UNDER FINISH FLOOR)
SUBFLOOR
A
INSULATION BATT WITH VAPOR BARRIER
WOOD STRIP
JOIST
VAPOR BARRIER
WIRE MESH
B
VAPOR BARRIER
SUBFLOOR
WOOD "SPRING" STRIP
JOIST
INSULATION BATT WITH VAPOR BARRIER
C

Figure 11.—Installation of vapor barriers and insulation in floor (unheated crawl space): A, Friction-type batts; B, wire mesh support; C, wood strip support.

When only a small amount of insulation is required between the joists because of moderate climates, several other insulating materials can be used. One such material is reflective insulation which usually consists of a kraft paper with aluminum foil on each face. The reflective face must be placed at least 3/4 inch away from the underside of the subfloor or other facing to be fully effective (Figure 12, A). Multiple or expanded reflective insulation might also be used. A thin blanket insulation can also be used between the joists as shown in Figure 12, B. This is ins alled in much the same manner as thicker insulation shown in Figure 10 or 11. When vapor barriers are a part of the flexible insulation and properly installed, no additional vapor barrier is ordinarily required.

HEATED CRAWL SPACE. -One method of heating which is sometimes used for crawl space houses, utilizes the crawl space as a plenum

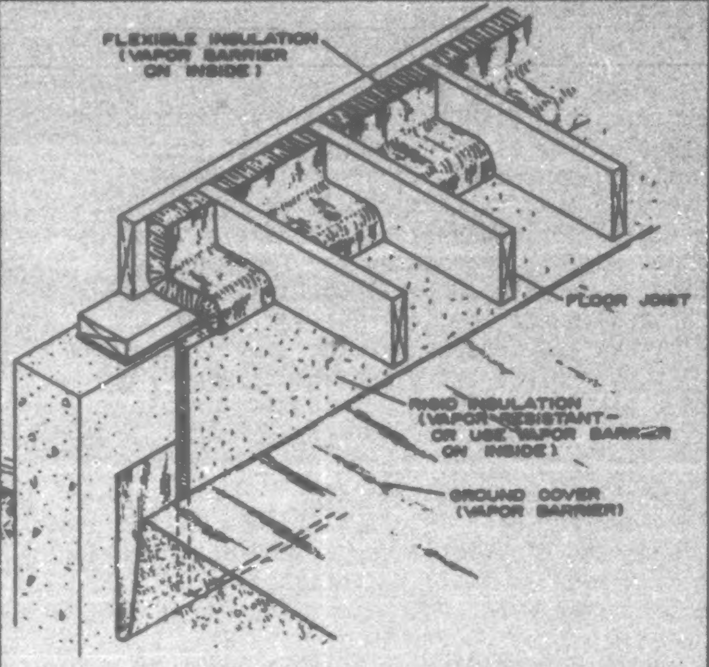

FLEXIBLE INSULATION
(VAPOR BARRIER
ON INSIDE)
FLOOR JOIST
RIGID INSULATION
(VAPOR-RESISTANT—
OR USE VAPOR BARRIER
ON INSIDE)
GROUND COVER
(VAPOR BARRIER)

Figure 13.—Installation of vapor barrier and insulation in heated crawl space.

chamber. Warm air is forced into the crawl space, which is somewhat shallower than those normally used without heat, and through wall-floor registers, around the outer walls, into the rooms above. When such a system is used, insulation is placed along the perimeter walls as shown in Figure 13. Flexible insulation, with the vapor barrier facing the interior, is used between joists; at the top of the foundation wall. A rigid insulation such as expanded polystyrene is placed along the inside of the wall, extending below the groundline to reduce heat loss. Insulation may be held in place with an approved mastic adhesive.

To protect the insulation moisture and to prevent moisture entry into the crawl space from the soil, a vapor barrier is used over the insulation below the groundline, Figure 13. Seams of the ground cover should be lapped and held in place with bricks or other bits of masonry. Some builders pour a thin concrete slab over the vapor barrier. The crawl space of such construction is seldom ventilated.

In crawl space houses, as well as other types, the finish grade outside the house should be sloped to drain water away from the foundation wall.

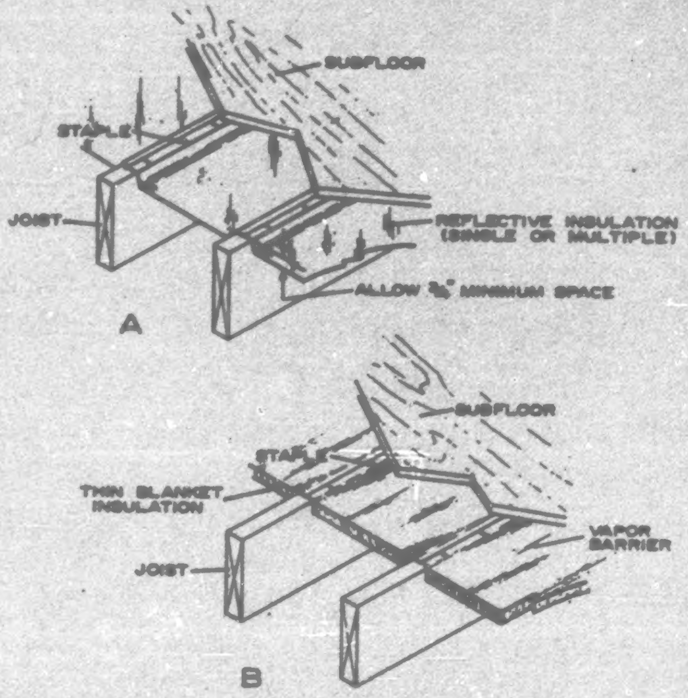

SUBFLOOR
STAPLE
JOIST
REFLECTIVE INSULATION
(SINGLE OR MULTIPLE)
ALLOW ¾" MINIMUM SPACE
A
SUBFLOOR
STAPLE
THIN BLANKET
INSULATION
JOIST
VAPOR
BARRIER
B

Figure 12.—Installation of vapor barriers and insulation over crawl space: A, Reflective insulation; and B, thin blanket insulation.

FINISHED BASEMENT ROOMS

Finished rooms in basement areas with fully or partly exposed walls should be treated much the same as a framed wall with respect to the use of vapor barriers and insulation (Figure 14). When a full masonry wall is involved, several factors should be considered: (a) When drainage in the area is poor and soil is wet, drain tile should be installed on the outside of the footing for removing excess water; (b) in addition to an exterior wall coating, a waterproof coating,should also be applied to the interior surface of the masonry to insure a dry wall; and (c) a vapor barrier should be used under the concrete floor slab to protect untreated wood sleepers or other materials from becoming wet.

Furring strips (2- by 2- or 2- by 3-inch members) used on the wall provide (a) space for the blanket insulation with the attached vapor barrier and (b) nailing surfaces for interior finish, Figure 14. One- or 1-1/2 inch thicknesses of friction-type insulation with a vapor barrier of plastic film such as 4-mil polyethylene or other materials might also be used for the walls.

Other materials which are used over masonry walls consist of rigid insulation such as expanded polystyrene. These are installed with a thin flurry of cement mortar and the wall completed with a plaster finish. The expanded plastic insulations normally have moderate resistance to vapor movement and require no other vapor barrier.

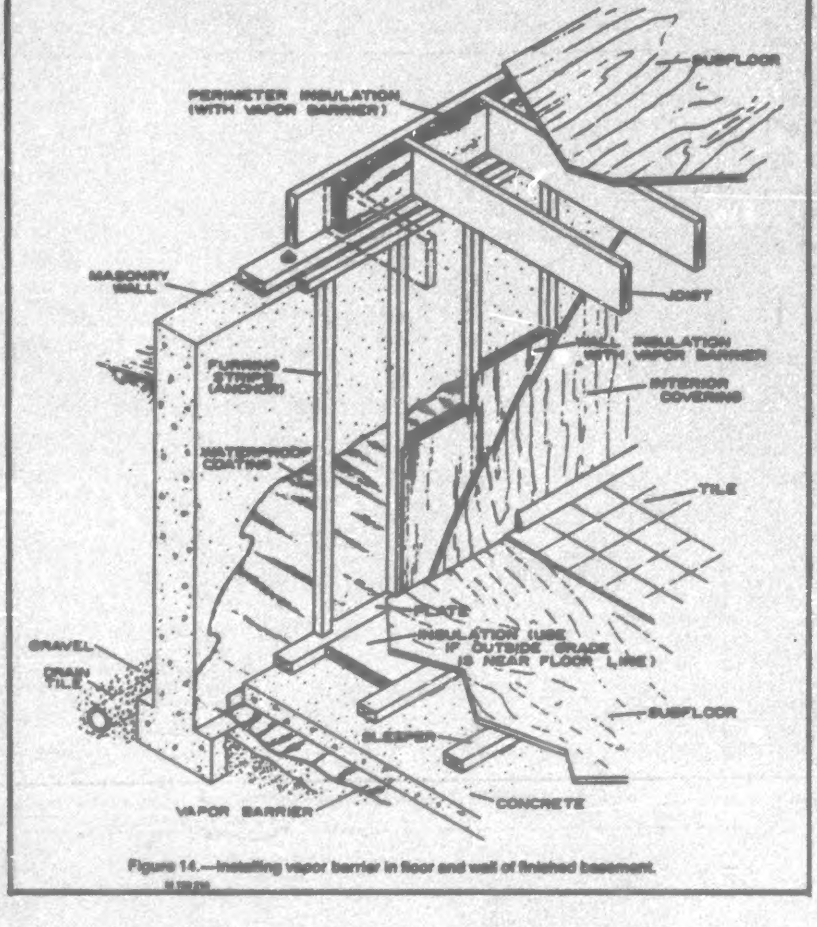

SUBFLOOR
PERIMETER INSULATION (WITH VAPOR BARRIER)
MASONRY WALL
JOIST
WALL INSULATION WITH VAPOR BARRIER
FURRING STRIPS (ANCHOR)
INTERIOR COVERING
WATERPROOF COATING
TILE
PLATE
INSULATION (USE IF OUTSIDE GRADE IS NEAR FLOOR LINE)
GRAVEL
DRAIN TILE
SUBFLOOR
SLEEPER
CONCRETE
VAPOR BARRIER

Figure 14.—Installing vapor barrier in floor and wall of finished basement.

When a vapor barrier has not been used under the concrete slab, it is good practice to place some type over the slab itself before applying the sleepers. One such system for unprotected in-place slabs involves the use of treated 1- by 4-inch sleepers fastened to the slab with a mastic. This if followed by the vapor barrier and further by second sets of 1- by 4-inch sleepers placed over and nailed to the first set. Subfloor and finish floor are then applied over the sleepers.

When the outside finish grade is near the level of the basement floor, it is usually good practice to use perimeter insulation around the exposed edges (Figure 14).

To prevent heat loss and minimize escape of water vapor, blanket or batt insulation with attached vapor barriers should be used around the perimeter of the floor framing above the foundation wall (Figure 14). Place the insulation between the joists or along stringer joists with the vapor barrier facing the basement side. The vapor barrier should fit tightly against the joists and subfloor.

WALLS

BLANKET INSULATION. -Flexible insulation in blanket or batt form is normally manufactured with a vapor barrier. These vapor barriers contain tabs at each side, which are stapled to the frame members. To minimize vapor loss and possible condensation problems, the best method of attaching consists of stapling the tabs over the edge of the studs (Figure 15). However, many contractors do not follow this procedure because it is more difficult and may cause some problems in nailing of the rock lath or dry wall to the studs. This usually results in some openings along the edge of the vapor barrier and, of course a chance for vapor to escape and cause problems. When insulation is placed in this manner, it is well to use a vapor barrier over the entire wall. This method is described in the next section.

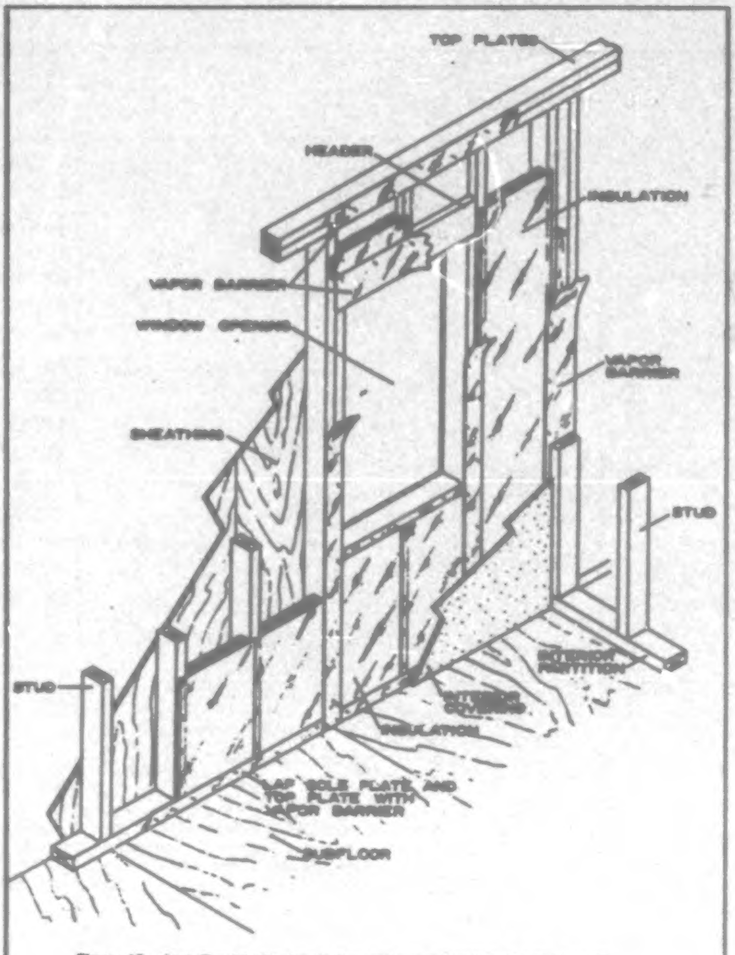

TOP PLATES
HEADER
INSULATION
VAPOR BARRIER
WINDOW OPENING
VAPOR BARRIER
SHEATHING
STUD
STUD
INTERIOR PARTITION
INTERIOR COVERING
INSULATION
LAP SOLE PLATE AND TOP PLATE WITH VAPOR BARRIER
SUBFLOOR

Figure 15.—Installing blanket insulation and vapor barriers in exterior wall.

Another factor in the use of flexible insulation having an integral vapor barrier is the protection required around window and door openings. Where the vapor barrier on the insulation does not cover doubled studs and header areas, additional vapor barrier materials should be used for protection (Figure 15). Most well-informed contractors include such details in the application of their insulation.

At junctions of interior partitions with exterior walls, care should be taken to cover this intersection with some type of vapor barrier. For best protection, insulating the space between the doubled exterior wall studs and the application of a vapor barrier should be done before the corner post is assembled (Figure 15). However, the vapor barrier should at least cover the stud intersections at each side of the partition wall.

FRICTION-TYPE INSULATION.-Some of the newer insulation forms, such as the friction-type without covers, have resulted in the development of a new process of installing insulation and vapor barriers so as to practically eliminate condensation problems in the walls. An unfaced friction-type insulation batt is ordinarily supplied without a vapor barrier, is semi-rigid, and made to fit tightly between frame members spaced 16 or 24 inches on center. "Enveloping" is a process of installing a vapor barrier over the entire wall (Figure 16). This type vapor barrier often consists of 4-mil or thicker polyethylene or similar material used in 8-foot-wide rolls. After insulation has been placed, rough wiring or duct work finished, and window frames installed, the vapor barrier is placed over the entire wall, stapling when necessary to hold it in place. Window and door headers, top and bottom plates, and other framing are completely covered (Figure 16). After rock lath plaster base or dry-wall finish is installed, the vapor barrier can be trimmed around window openings.

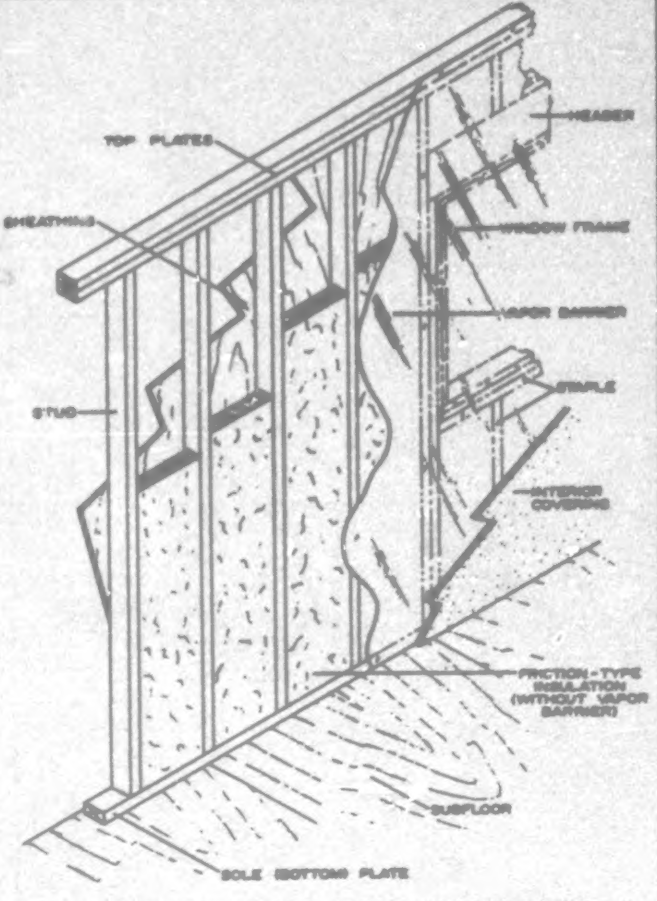


Figure 16.—Installing vapor barrier over friction-type insulation (enveloping).

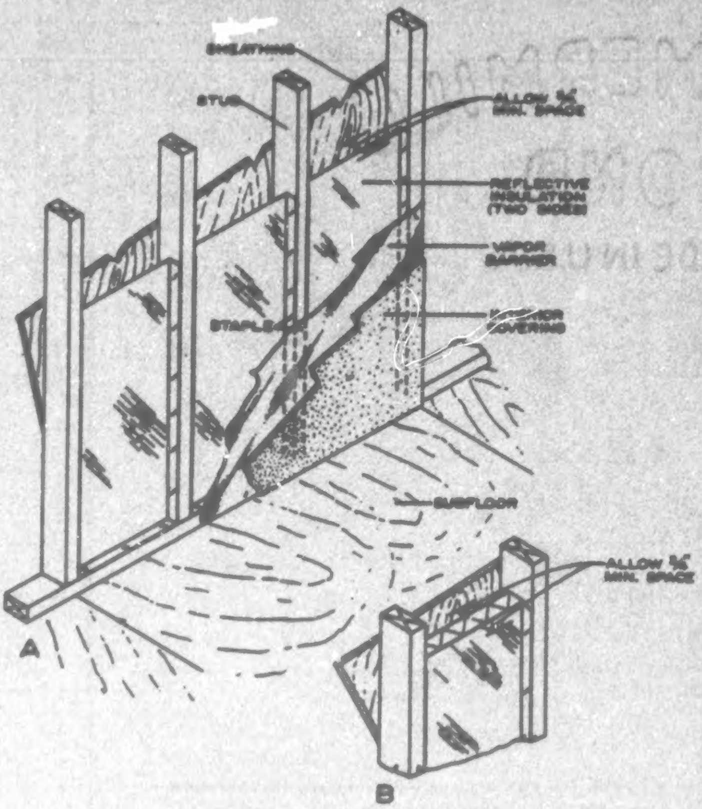


Figure 17.—Installing reflective insulation: A, Single sheet, reflective two sides; B, multiple reflective insulation.

REFLECTIVE INSULATIONS. -Reflective insulations ordinarily consist of either a kraft sheet faced on two sides with aluminum foil, Figure 17, A, or the multiple-reflective "accordion" type, Figure 17, B. Both are made to use between studs or joists. To be effective, it is important in using such insulation that there is at least a 3/4-inch space between the reflective surface and the wall, floor, or ceiling surface. When a reflective insulation is used, it is good practice to use a vapor barrier over the studs or joists. The barrier should be placed over the frame members just under the dry wall or plaster base (Figure 17, A). Gypsum board commonly used as a dry wall finish can be obtained with an aluminum foil on the inside face which serves as a vapor barrier. When such material is used, the need for a separate vapor barrier is eliminated.

TWO-STORY HOUSE. -One of the areas of a two-story house where the requirement of a vapor barrier and insulation is often overlooked is at the perimeter area of the second floor joists. The space between the joists at the header and along the stringer joists should be protected by sections of batt insulation which contain a vapor barrier (Figure 18). The sections should fit tightly so that both the vapor barriers and the insulation fill the joist spaces.

A two-story house is sometimes designed so that part of the second floor projects beyond the first. This projection varies but is often about 12 inches. In such designs, the projections should be insulated and vapor barriers installed as shown in Figure 19.

Insulation and vapor barriers in exposed second floor walls (Figure 18) should be installed in the same manner as for walls of single-story houses. This might include: (a) standard blanket insulation with its integral vapor barrier; (b) friction-type insulation with separate vapor barrier (Figure 16); or (c) reflective insulation with the protective vapor barrier (Figure 17).

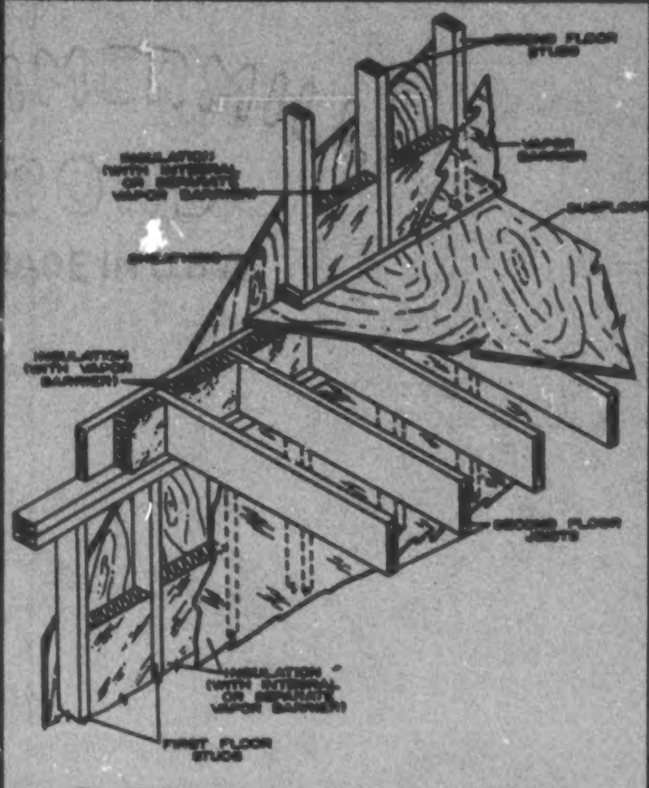

SECOND FLOOR STUDS
VAPOR BARRIER
INSULATION (WITH INTEGRAL OR SEPARATE VAPOR BARRIER)
SUBFLOOR
SHEATHING
INSULATION (WITH VAPOR BARRIER)
SECOND FLOOR JOISTS
INSULATION (WITH INTEGRAL OR SEPARATE VAPOR BARRIER)
FIRST FLOOR STUDS

Figure 18.—Vapor barriers in walls and joist space of two-story house.

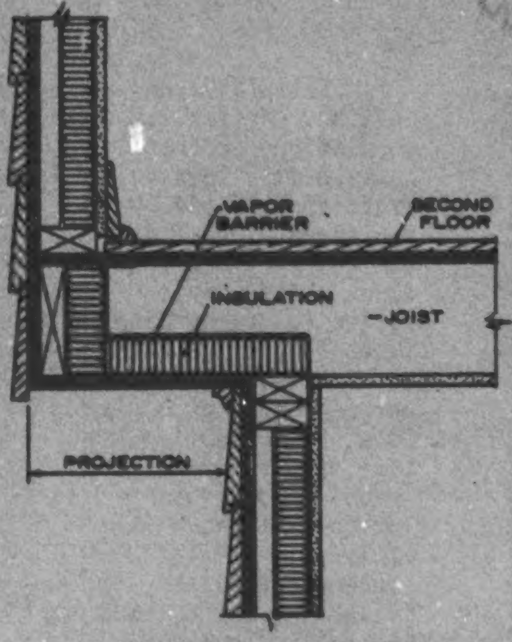

VAPOR BARRIER
SECOND FLOOR
INSULATION
JOIST
PROJECTION

Figure 19.—Insulation and vapor barrier at second floor projection.

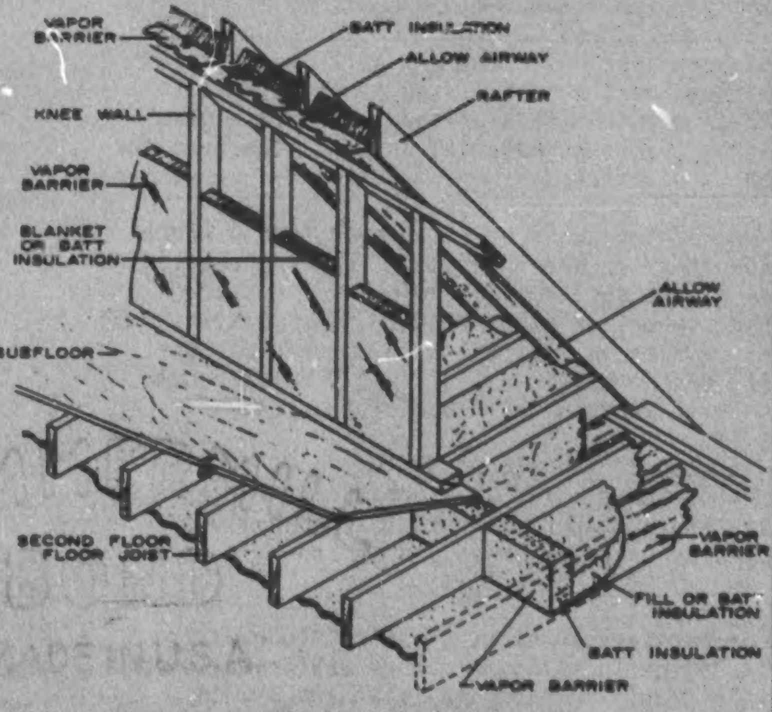

VAPOR BARRIER
BATT INSULATION
ALLOW AIRWAY
KNEE WALL
RAFTER
VAPOR BARRIER
BLANKET OR BATT INSULATION
ALLOW AIRWAY
SUBFLOOR
SECOND FLOOR FLOOR JOIST
VAPOR BARRIER
FILL OR BATT INSULATION
BATT INSULATION
VAPOR BARRIER

Figure 20.—Installing vapor barrier and insulation in knee-wall areas of 1-1/2-story house.

KNEE WALLS. -In 1-1/2-story houses containing bedrooms and other occupied rooms on the second floor, it is common practice to include knee walls. These are partial walls which extend from the floor to the rafters (Figure 20). Their height usually varies between 4 and 6 feet. Such areas must normally contain vapor barriers and insulation in the following areas: (a) In the first floor ceiling area, (b) at the knee wall, and (c) between the rafters. Insulation batts with the vapor barrier facing down should be placed between joists from the outside wall plate to the knee wall. The insulation should also fill the entire joist space directly under the knee wall (Figure 20). Care should be taken when placing the insulating batt to allow an airway for attic ventilation at the junction of the rafter and exterior wall.

Insulation in the knee wall can consist of blanket or batt-type insulation with integral vapor barrier or with separately applied vapor barriers, as described-for first and second floor walls.

Batt or blanket insulation is commonly used between the rafters at the sloping portion of the heated room, Figure 20. As in the application of all insulations, the vapor barrier should face the inner or warm side of the roof or wall. An airway should always be allowed between the top of the insulation and the roof sheathing at each rafter space. This should be at least 1-inch clear space without obstructions such as might occur with solid blocking. This will allow movement of air in the area behind the knee wall to the attic area above the second floor rooms (Figure 6).

CEILINGS AND ATTICS

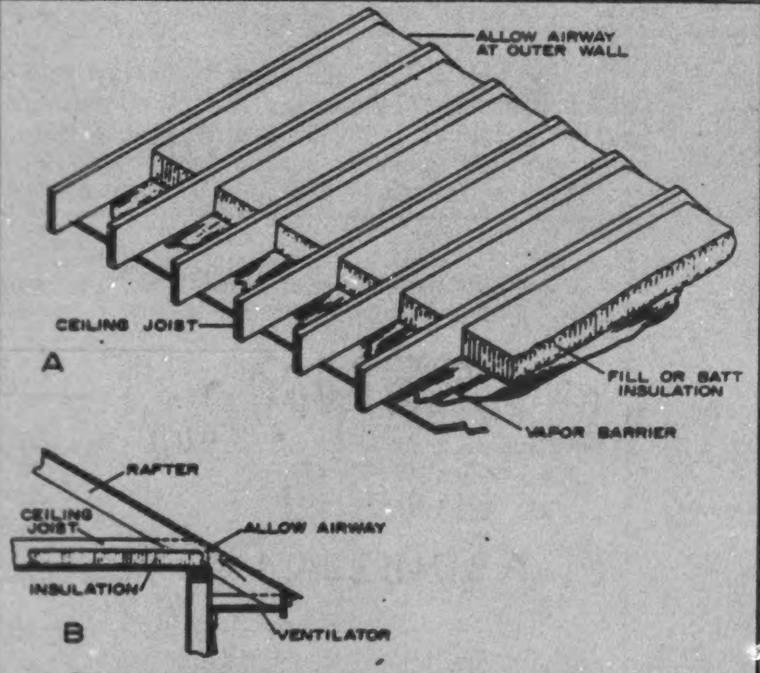


Figure 21.—Installing ceiling insulation and vapor barrier: A, Vapor barrier and insulation; and B, airway for ventilation.

VAPOR BARRIERS AND INSULATION. -Insulation in ceiling areas normally consists of the batt or fill-type. However, to provide for good condensation control, a vapor barrier should always be provided (Figure 21, A). When an insulation batt is supplied with a vapor barrier on one face, no additional protection is normally required. Place the batts with barrier side down, so that they fit tightly between ceiling joists. Batts with the vapor barrier attached can also be stapled to the bottom edge of the joists before the ceiling finish is applied. At the junction of the outside walls and rafters, a space should always be left below the roof boards to provide a ventilating airway (Figure 32, B).

VENTILATION. -Ventilation of attic spaces and roof areas is important in minimizing water vapor buildup. However, while good ventilation is important, there is still a need for vapor barriers in ceiling areas. This is especially true of the flat or low-sloped roof where only a 1- to 3-inch space above the insulation might be available for ventilation.

In houses with attic spaces, the use of both inlet and outlet ventilation is recommended. Placing inlet ventilators in soffit or frieze-board areas of the cornice and outlet ventilators as near the ridge-line as possible will assure air movement through a "stack" effect. This is due to the difference in height between inlet and outlet ventilators and normally assures air movement even on windless days or nights.

RECOMMENDED VENTILATING AREAS. -The minimum amount of attic or roof space ventilation required is determined by the total ceiling area. These ratios are shown in Figures 22, 23, and 24 for various types of roofs. The use of both inlet and outlet ventilators is recommended whenever possible. The total net area of ventilators is found by application of the ratios shown in Figures 22, 23, and 24. The total area of the ventilators can be found by using the data in Table 2. Divide this total area by the number of ventilators used to find the recommended square-foot area of each.

For example, a gable roof similar to Figure 22, B with inlet and outlet ventilators has a minimum required total inlet and outlet ratio of 1/900 of the ceiling area. If the ceiling area of the house is 1,350 square feet, each net inlet and outlet ventilating area should be 1,350 divided by 900 or 1-1/2 square feet.

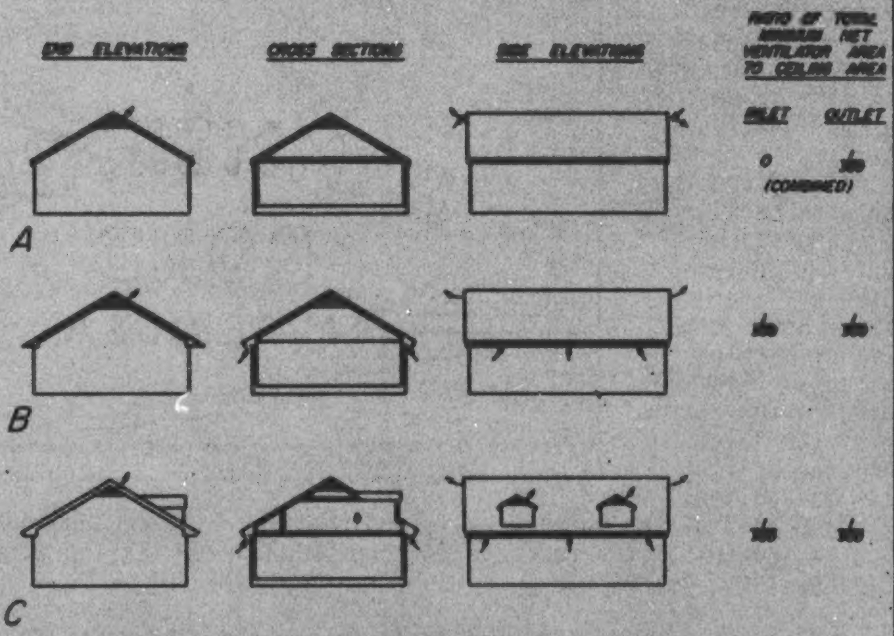


Figure 22.—Ventilating areas of gable roofs: A, Louvers in end walls; B, louvers in end walls with additional openings at eaves; C, louvers at end walls with additional openings at eaves and dormers. Cross section of C shows free opening for air movement between roof boards and ceiling insulation of attic room.

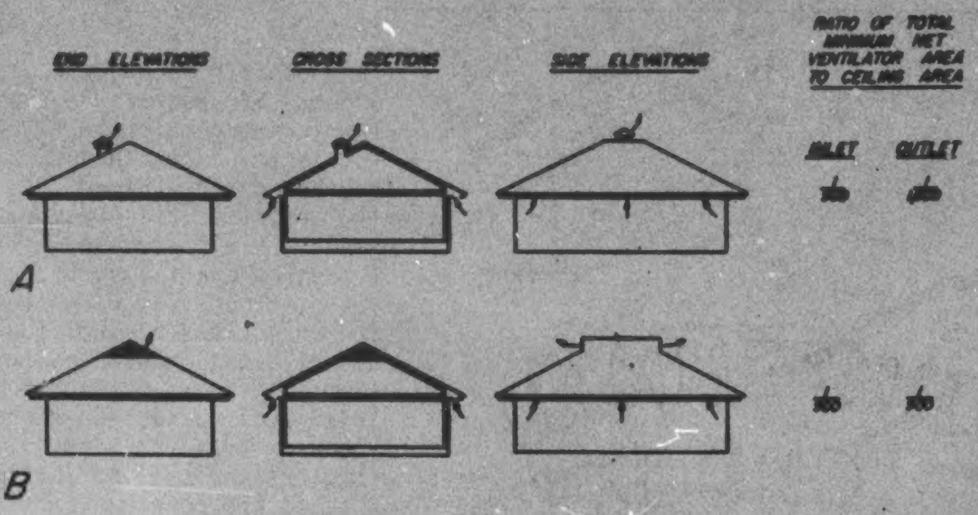

END ELEVATIONS
CROSS SECTIONS
SIDE ELEVATIONS
RATIO OF TOTAL MINIMUM NET VENTILATOR AREA TO CEILING AREA
INLET
OUTLET
A
B

Figure 23.—Ventilating areas of hip roofs: A, Inlet openings beneath eaves and outlet vent near peak; B, inlet openings beneath eaves and ridge outlets.

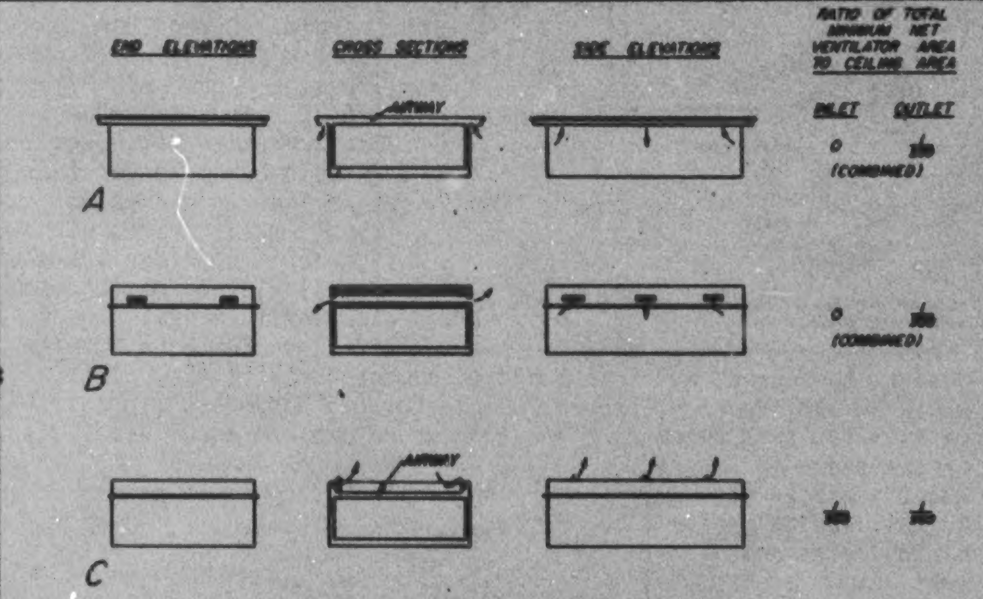

END ELEVATIONS
CROSS SECTIONS
SIDE ELEVATIONS
RATIO OF TOTAL MINIMUM NET VENTILATOR AREA TO CEILING AREA
INLET
OUTLET
AIRWAY
0
(COMBINED)
A
0
(COMBINED)
B
AIRWAY
C

Figure 24.—Ventilating area of flat roofs: A, Ventilator openings under overhanging eaves where ceiling and roof joists are combined; B, for roof with a parapet where roof and ceiling joists are separate; C, for roof with a parapet where roof and ceiling joists are combined.

If ventilators are protected with No. 16-mesh insect screen and plain metal louvers, Table 2, the minimum gross area must be 2x1-1/2 or 3 square feet. When one outlet ventilator is used at each gable end, each should have a gross area of 1-1/2 square feet (3 divided by 2). When distributing the soffit inlet ventilators to three on each side, for a small house (total of 6), each ventilator should have a gross area of 0.5 square feet. For long houses, use 6 or more on each side.

INLET VENTILATORS. -Inlet ventilators in the soffit may consist of several designs. It is good practice to distribute them as much

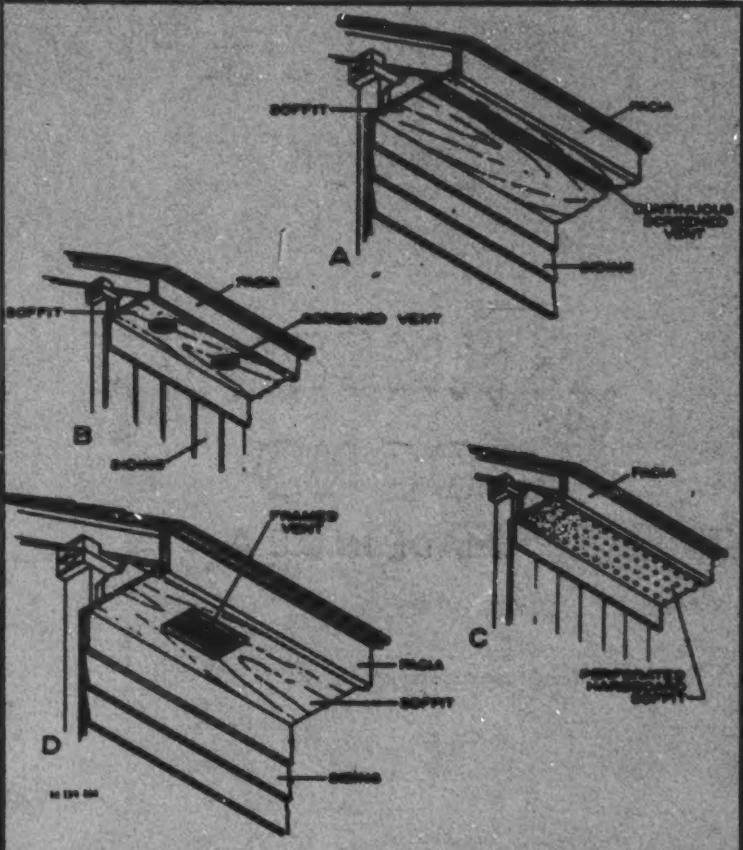

SOFFIT
FACIA
CONTINUOUS SCREENED VENT
A
SIDING
FACIA
SOFFIT
SCREENED VENT
B
SIDING
FRAMED VENT
FACIA
C
PERFORATED HARDBOARD SOFFIT
FACIA
SOFFIT
D
SIDING

Figure 25.—Inlet ventilators in soffits: A, Continuous vent; B, round vents; C, perforated; D, single ventilator.

as possible to prevent "dead" air pockets in the attic where moisture might collect. A continuous screened slot, Figure 25, A, satisfies this requirement. Small screened openings might also be used, Figure 25, B. Continuous slots or individual ventilators between roof members should be used for flat-roof houses where roof members serve as both rafters and ceiling joists. Locate the openings away from the wall line to minimize the possible entry of wind-driven snow. A soffit consisting of perforated hardboard, Figure 25, C, can also be used to advantage but holes should be no larger than 1/8 inch in diameter. Small metal frames with screened openings are also available and may be used in soffit areas, Figure 25, D. For open cornice design, the use of a frieze board with screen ventilating slots would be satisfactory, Figure 26. Perforated hardboard might also be used for this purpose. The recommended minimum inlet ventilating ratios shown in Figures 22, 23, and 24 should be followed in determining total net ventilating areas for both inlet and outlet ventilators.

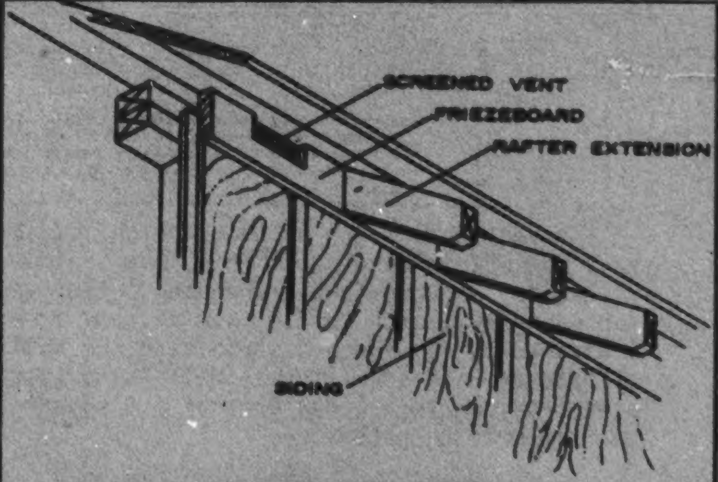

SCREENED VENT
FRIEZEBOARD
RAFTER EXTENSION
SIDING

Figure 26.—Frieze ventilator (for open cornice).

OUTLET VENTILATORS. -Outlet ventilators to be most effective should be located as close to the highest portion of the ridge as possible. They may be placed in the upper wall section of a gable-roofed house in various

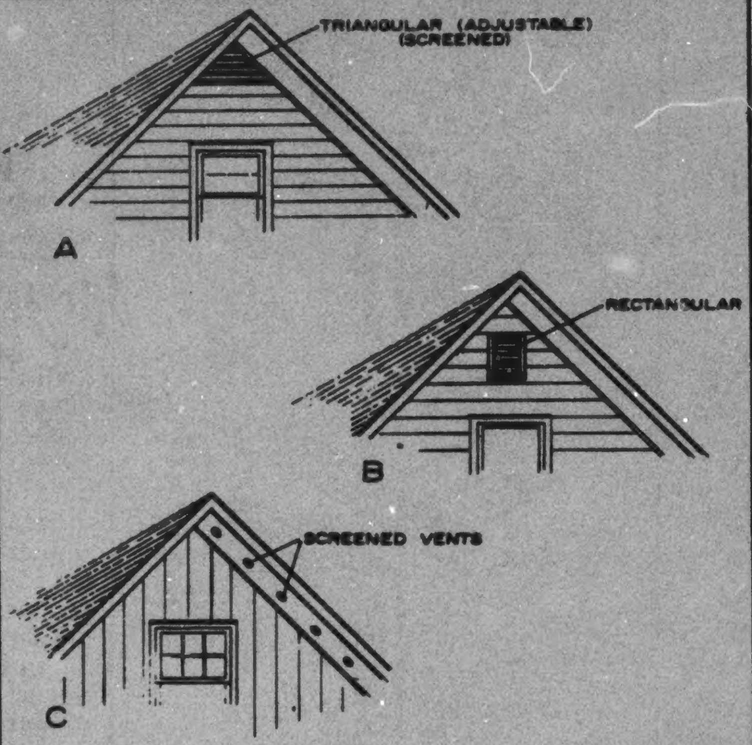

TRIANGULAR (ADJUSTABLE)
(SCREENED)
A
RECTANGULAR
B
SCREENED VENTS
C

Figure 27.—Gable outlet ventilators: A, Triangular gable and ventilator; B, rectangular gable and ventilator; C soffit ventilators.

forms as shown in Figure 27, A and B. In wide gable-end overhangs with ladder framing, a number of screened openings can be located in the soffit area of the lookouts (Figure 27, C). Ventilating openings to the attic space should not be restricted by blocking. Outlet ventilators on gable or hip roofs might also consist of some type of roof ventilator (Figure 28, A and B). Hip roofs can utilize a ventilating gable (modified hip) (Figure 28, C). Protection from blowing snow must considered, which often restricts the use of a continuous ridge vent. Locate the single roof ventilators (Figure 28, A and B) along the ridge toward the rear of the house so they are not visible from the front. Outlet ventilators might also be located in a chimney as a false flue which has a screened opening to the attic.

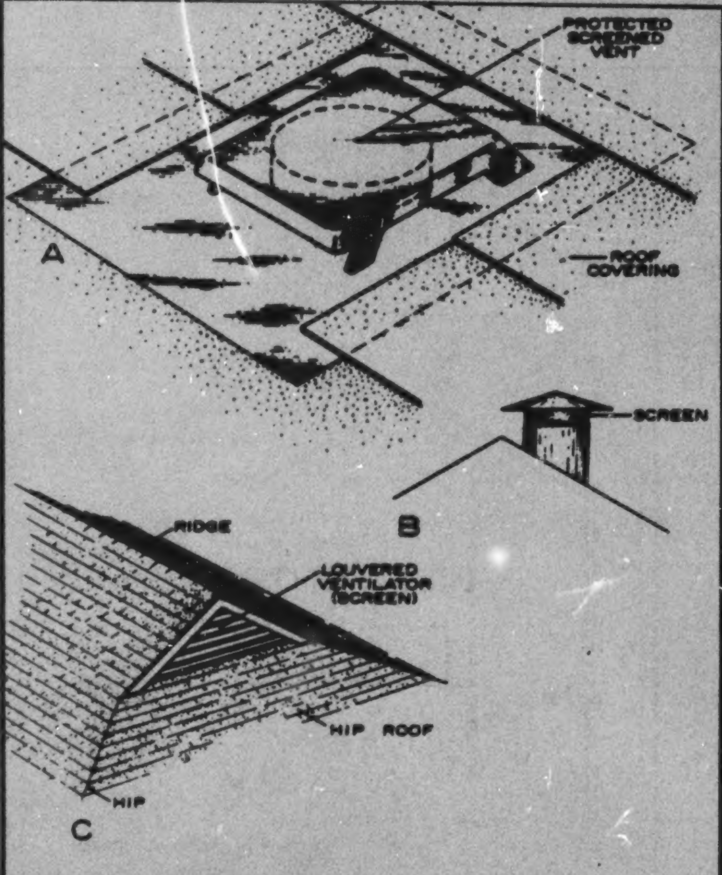

PROTECTED
SCREENED
VENT
A
ROOF
COVERING
SCREEN
B
RIDGE
LOUVERED
VENTILATOR
(SCREEN)
HIP ROOF
HIP
C

Figure 28.—Ridge outlet ventilators: A, Low silhouette type; B, pipe ventilator type; C, modified hip ventilator.

OTHER PROTECTIVE MEASURES

SNOW AND ICE DAMS. -Water leakage into walls and interiors of houses in the snow belt areas of the country is sometimes caused by ice dams and is often mistaken for condensation. Such problems occur after heavy snowfalls when there is sufficient heat loss from the living quarters to melt the snow along the roof surface. The water

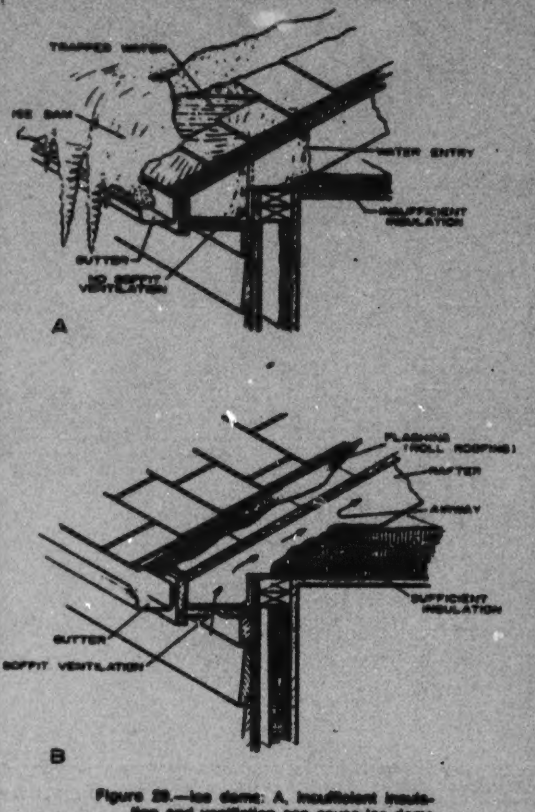

TRAPPED WATER
ICE DAM
WATER ENTRY
INSUFFICIENT INSULATION
GUTTER
NO SOFFIT VENTILATION
A
FLASHING (ROLL ROOFING)
RAFTER
AIRWAY
SUFFICIENT INSULATION
GUTTER
SOFFIT VENTILATION
B

Figure 29.—Ice dams: A, insufficient insulation and ventilation can cause ice dams and water damage; B, good ventilation, insulation, and roof flashing minimize problems.

moves down the roof surface to the colder overhang of the roof where it freezes. This causes a ledge of ice and backs up water, which can enter the wall or drip down onto the ceiling finish (Figure 29, A).

Ice dam problems can be minimized if not entirely eliminated. By reducing attic temperatures by adequate insulation and ventilation, snow melting at the roof surface is greatly reduced. Good insulation, 6 inches or more in the northern sections of the country, greatly reduces heat loss from the house proper. Adequate ventilation, in turn, tends to keep attics dry with temperatures only slightly above outdoor temperatures. This combination of good ventilation and insulation is the answer to reducing ice dam problems.

Another protective measure is provided by the use of a flashing material. A 36-inch width of 45-pound roll roofing along the eave line will provide such added protection (Figure 29, B).

PROTECTION AT UNHEATED AREAS. - Walls and doors to unheated areas such as attic spaces should be treated to resist water vapor movement as well as to minimize heat loss. This includes the use of insulation and vapor barriers on all wall areas adjacent to the cold attic (Figure 30). Vapor barriers should face the warm side of the room. In addition, some means should be used to prevent

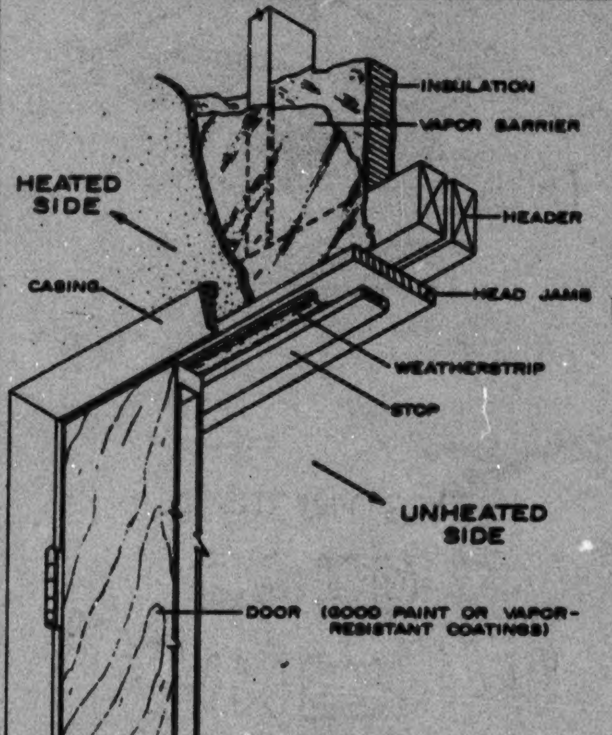

INSULATION
VAPOR BARRIER
HEATED SIDE
HEADER
CASING
HEAD JAMB
WEATHERSTRIP
STOP
UNHEATED SIDE
DOOR (GOOD PAINT OR VAPOR-RESISTANT COATINGS)

Figure 30.—Insulating door to unheated attic space.

heat and vapor loss around the perimeter of the door. One method is through some type of weather strip (Figure 30). The door itself should be given several finish coats of paint or varnish which will resist the movement of water vapor.

If further resistance to heat loss is desired, a covering of 1/2 inch or thicker rigid insulation, such as insulation board or foamed plastic, can be attached to the back of the door.

PROTECTION AT OUTLET BOXES. -Outlet or switch boxes or other openings in exposed (cold) walls often are difficult to treat to prevent water vapor escape. Initially, whether the vapor barrier is a separate sheet or part of the insulation, as tight a fit as possible should be made when trimming the barrier around the box (Figure 31). This is less difficult when the barrier is separate. As an additional precaution, a bead of caulking compound should be applied around the box after the dry wall or the plaster base has been installed (Figure 31). The same caulking can be used around the cold-air return ducts or other openings in exterior walls. This type of sealing may appear unnecessary, but laboratory tests have shown that there is enough moisture loss through the perimeter of an outlet box to form a large ball of frost on the back face during extended cold periods. Melting of this frost can adversely affect the exterior paint films. In the colder areas of the country and in rooms where there is excess water vapor, such as the bath and kitchen, this added protection is good insurance from future problems. Some switch and junction boxes are more difficult to seal than others because of their makeup. A simple polyethylene bag or other enclosure around such boxes will provide some protection.

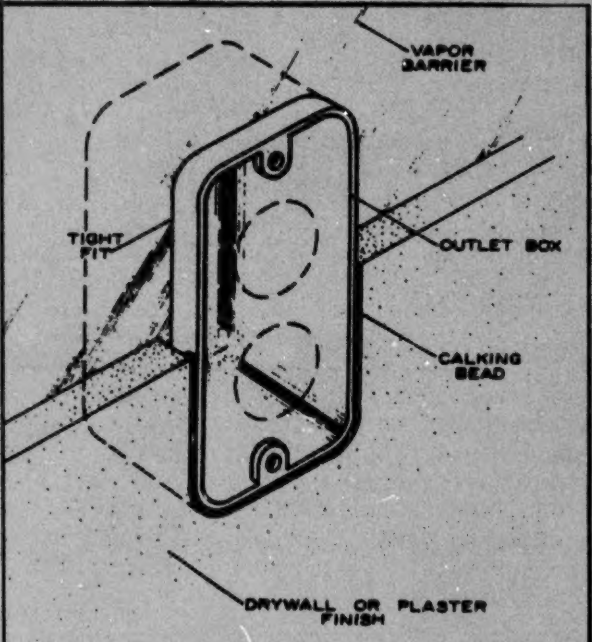


Figure 31.—Protection around outlet boxes in exposed walls.

Condensation problems caused by water-vapor movement through unprotected outlet box areas in exposed walls are often due to poor workmanship during application of the insulation. Figure 32 shows a section of exterior wall with the vapor barrier loosely stapled to the face of the studs. Because of poor application, a small space is sometimes left at the top and bottom of the insulation in the stud space. Water vapor escaping through the unprotected outlet box travels by convection, on the warm side, to the top of the wall, where it moves to the cold side and condenses on the inner face of the colder siding or sheathing. Continued movement of vapor can saturate these materials and in severe conditions cause decay. Buckling of single panel siding, such as hardboard or similar materials, can result as moisture content of the material increases. Such problems can be minimized by "enveloping" of the inner face of exposed walls with a vapor barrier, as previously outlined (Figure 16). Sealing the outlet box in some manner will also aid in restricting water vapor movement into the wall cavity.

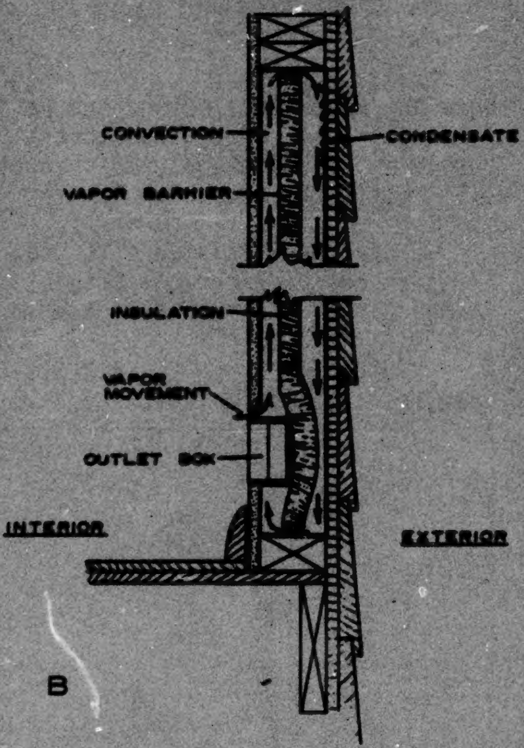


Figure 22.—Results of water vapor loss around outlet box.

OTHER OPENINGS. -The same principles used in sealing outlet boxes should be applied to all openings in an outside wall or ceiling. Openings may include exhaust fans in the kitchen or the bathroom, hot air registers, cold air return registers, and plumbing. Openings are also required in ceilings for light fixtures, ventilation fans, and plumbing vents. Regardless of the type of opening, the vapor barrier should be trimmed to fit as tightly as possible.

How To Minimize Existing Condensation

Condensation problems can be eliminated by specifying proper construction details during planning of the house. Correct placement of vapor barriers, adequate insulation, the use of attic ventilation, and other good practices can be incorporated at this time. These recommendations have been outlined and illustrated in the preceding sections. However, when one or more of these details have not been included in an existing house and condensation problems occur, they are often more difficult to solve. Nevertheless, there are methods which can be used to minimize such condensation problems after the house has been constructed.

VISIBLE CONDENSATION

GLASS SURFACES. -Visible surface condensation on the interior glass surfaces of windows can be minimized by the use of storm windows or by replacing single glass with insulated glass. However, when this does not prevent condensation on the surface, the relative humidity in the room must be reduced. Drapes or curtains across the windows hinder rather than help. Not only do they increase surface condensation because of colder glass surfaces, but they also prevent the air movement that would warm the glass surface and aid in dispersing some of the moisture.

ATTIC AREAS. -Condensation or frost on protruding nails, on the surfaces of roof boards, or other members in attic areas normally indicates the escape of excessive amounts of water vapor from the heated rooms below. If a vapor barrier is not already present, place one between joists under the insulation. Make sure the vapor barrier fits tightly around ceiling lights and exhaust fans, calking if necessary. In addition, increase both inlet and outlet ventilators to conform to the minimum recommendations in Table 2. Decreasing the amount of water vapor produced in the living areas is also helpful.

CRAWL SPACES. -Surface condensation in unheated crawl spaces is usually caused by excessive moisture from the soil or from warm humid air entering from outside the house. To eliminate this problem, place a vapor barrier over the soil as shown in Figure 10; if necessary, use the proper amount of ventilation as recommended in Table 1.

CONCRETE SLABS. -Concrete slabs without radiant heat are sometimes subjected to surface condensation in late spring when warm humid air enters the house. Because the temperature of some areas of the concrete slab or its covering is below the dewpoint, surface condensation can occur. Keeping the windows closed during the day, using a dehumidifier, and raising the inside temperature aid in minimizing this problem. When the concrete slab reaches normal room temperatures, this inconvenience is eliminated.

REDUCING RELATIVE HUMIDITY

Reducing high relative humidities within the house to permissible levels is often necessary to minimize condensation problems. Discontinuing the use of room-size humidifiers or reducing the output of automatic humidifiers until conditions are improved is helpful. The use of exhaust fans and dehumidifiers can also be of value in eliminating high relative humidities within the house. When possible, decreasing the activities which produce excessive moisture, as discussed in a previous section, is sometimes necessary. This is especially important for homes with electric heat.

CONCEALED CONDENSATION

Concealed condensation is, in essence, a surface or similar condensation that takes place within a component such as a wall cavity when a condensing surface is below the dewpoint. In cold weather, condensation often forms as frost. Such conditions can cause staining of siding and peeling of the paint and possibly decay in severe and sustained conditions. These problems are usually not detected until spring after the heating season has ended. The remedies and solutions to the problems should be taken care of before repainting or residing is attempted. Several methods might be used to correct this problem.

(1) Reduce or control the relative humidity within the house as previously discussed.

(2) Add a vapor-resistant paint coating such as aluminum paint to the interior of walls and ceilings.

(3) Improve the vapor resistance of ceilings by adding a vapor barrier between ceiling joists.

(4) Improve attic ventilation (Figures 22, 23, and 24).

ICE DAM

Several methods can be used to minimize this problem caused by melting snow. By reducing the attic temperatures in the winter so that they are only slightly above outdoor temperatures, most ice dams can be eliminated. This can be accomplished in the following manner:

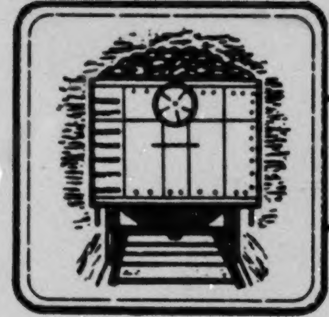
(1) Add insulation to the ceiling area in the attic to reduce heat loss from living areas below. This added insulation and ventilation will also be helpful by reducing summer temperatures in the living areas below.

(2) Provide additional inlet ventilation in the soffit area of the cornice as well as better outlet ventilation near the ridge.

(3) When reroofing, use a flashing strip of 36-inch-wide roll roofing paper of 45-pound weight along the eave line before reshingling. While this does not prevent ice dams, it is a worthwhile precaution.

(4) Under severe conditions, or when only some portions of a roof produce ice dams (such as at valleys), the use of electric-thermal wire laid in a zig-zag pattern and in gutters may prove effective. The wire is connected and heated during periods of snowfall and at other times as needed to maintain channels for drainage.

unit 4



HEATING SYSTEMS

by: L.K. Hans

Space heating can consume as much as 75% of the energy used in a home with 60% being the average for this area. This high energy usage makes it essential that the renter/homeowner be aware of the equipment used to produce heat. By proper selection, operation, and maintenance of heating systems the consumer of energy can make a significant contribution to the energy conservation effort.

A heating system is defined as the mechanical equipment used to heat a home. It produces this heat from electrical resistance, heat extraction, or from an open flame fueled by wood or fossil fuels like gas, oil, or coal. Heat can also be obtained from the sun.

Home Energy Conservation Primer

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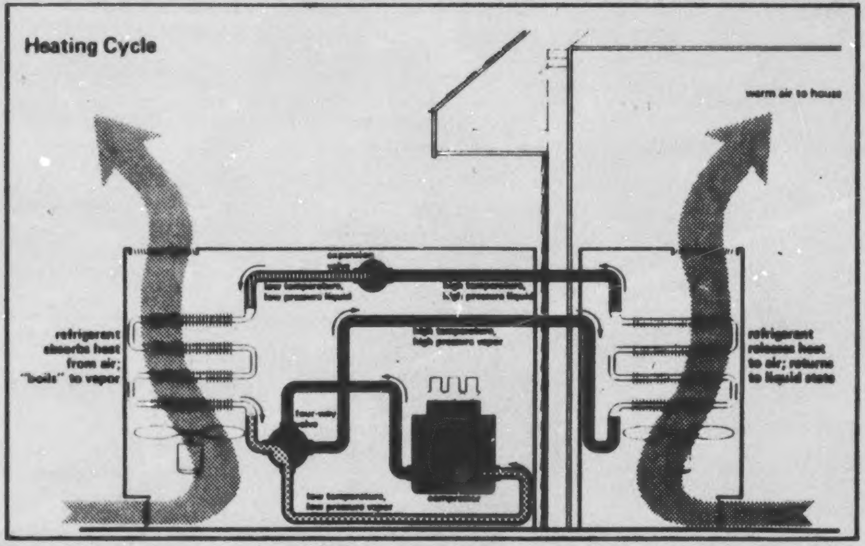
HEATING FUEL OPTIONS

Most homes are heated by electricity, oil, gas, or coal. There are also an increasing number of homes heated by wood or solar energy. Each of these sources can be utilized in different ways and have distinct advantages and disadvantages.

Electricity - The use of electricity for home heating can be effective and efficient but the dwelling must be properly insulated and weatherized or the cost can be very prohibitive. Electric heating systems fall into two types (1) central and (2) noncentral (self-contained).

Central electric heating systems include heat pumps, furnaces and boilers. Heat pumps are reversible refrigeration devices that extract heat from the outside air even when that air is very cold. If not enough heat is available from the air, electric resistance coils are activated to bring the air up to the proper temperature.


Heating Cycle
warm air to house
expansion valve
low temperature, low pressure liquid
high temperature, high pressure liquid
high temperature, high pressure vapor
refrigerant absorbs heat from air; "boils" to vapor
refrigerant releases heat to air; returns to liquid state
four-way valve
low temperature, low pressure vapor
compressor

Electric furnaces circulate resistance-produced heat through ducts to the various parts of the house in the same manner as a heat pump. Electric boilers are used to heat water which in turn is pumped to some type of heat exchanger, such as a radiator, which transfers the heat to the room air.

Non-central electric heating is made up of several types of equipment. Electric baseboard heaters heat by convection. When the cool air rises through the heated fins, the air picks up heat and rises creating a circular movement of air. Radiant ceiling heaters work

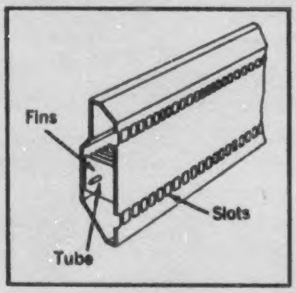

Fins
Slots
Tube

Figure 4.2

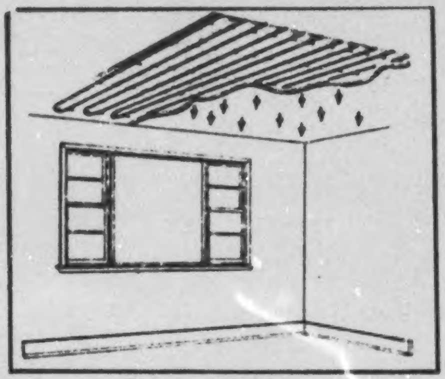


Figure 4.3

by radiating heat from cables or panels that are attached to the ceiling and covered with plaster. Floor insert heaters are often installed under large glass areas and in location where wall space is limited. Ceiling units are used to heat small areas and are often incorporated with lighting and exhaust fans. Wall units are concentrated heat sources used to heat whole rooms or smaller areas. Cove or valance heaters are surface mounted on walls near the ceiling and usually over windows.

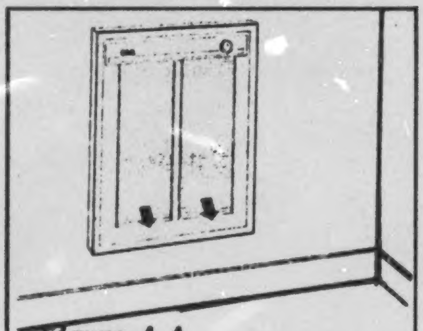


Figure 4.4
The better types of electric wall heaters discharge the warm air from the bottom and circulate it by means of a fan.

Oil - In the typical oil furnace heat is produced by mixing a spray of oil droplets with air and igniting it to give a flame. To extract the most heat from an oil furnace, the fuel must be burned completely. This is best accomplished when the furnace and oil burner are properly adjusted. Most oil furnaces use either gravity feed or forced air to distribute the warm air. Oil is an efficient way to heat but requires a large storage tank.

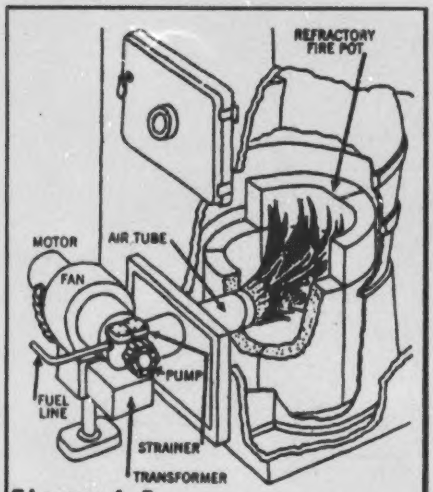

REFRACTORY FIRE POT
MOTOR
AIR TUBE
FAN
PUMP
FUEL LINE
STRAINER
TRANSFORMER

Figure 4.5
The gun or pressure type oil burner is the most popular for home central heating systems.

Natural Gas -
Natural gas is currently the most economical fossil fuel heating source. It is very efficient when used with the right equipment and requires no storage (except with LP or liquid

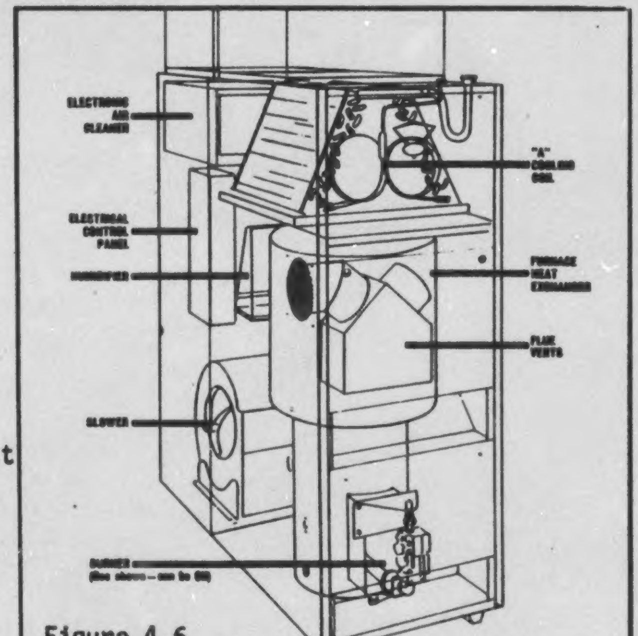

ELECTRONIC AIR CLEANER
"A" COOLING COIL
ELECTRICAL CONTROL PANEL
HUMIDIFIER
FURNACE HEAT EXCHANGER
FLUE VENTS
BLOWER
BURNER (Gas shown — can be Oil)

Figure 4.6

propane). In a gas-fired furnace the gas is supplied at low pressure through the burner head. It then mixes with the air, ignites, and burns with a blue flame. The warmed air is then distributed by a forced air system. Gas can also be used to heat water which is circulated through radiators and heats the house. These gas-fired boilers can also provide domestic hot water.

Coal - There are still a large number of homes heated with coal. A coal furnace is fairly simple since the coal is burned on a grate so that air can circulate under it. The flame heats a bonnet inside the furnace and the air circulating around this bonnet is used to heat the house. Coal is dirty, both for handling and burning, it requires a large storage area, and it must be stoked into the furnace either by hand or with some type of mechanical equipment.

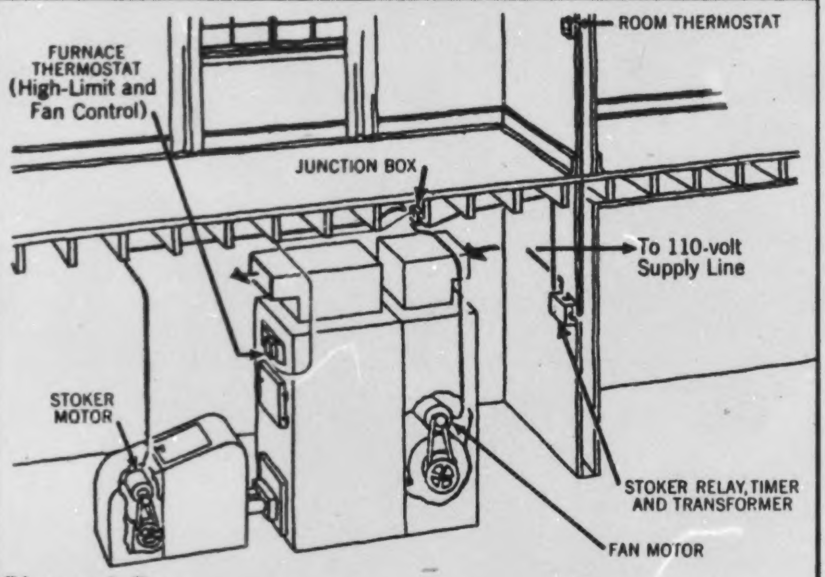

ROOM THERMOSTAT
FURNACE THERMOSTAT (High-Limit and Fan Control)
JUNCTION BOX
To 110-volt Supply Line
STOKER MOTOR
STOKER RELAY, TIMER AND TRANSFORMER
FAN MOTOR

Figure 4.7

—Controls for a stoker-fired coal burner with a forced-warm-air heating system.

Wood - Wood can be an effective, efficient source of home heating if burned in the proper heater. Wood is usually burned in fireplaces, wood stoves, or wood furnaces. Fireplaces and wood stoves rely on convection and radiation to distribute heat while a wood furnace usually supplies heated air through a duct system in the same manner as other forced air furnaces. Heating with wood will be discussed at length later in this unit.

Solar - Solar energy, or more specifically heat gained directly from the rays of the sun, can be used to heat a house. Usually the methods of using solar energy fall into two categories: active and passive. Active systems extract heat through mechanical means using liquid or air to transfer heat from a collecting device to the house. Passive systems use no mechanical devices but rather use the house itself as the collector by allowing the sun to shine in and warm the interior. Solar energy systems will also be discussed in greater detail later in this unit.

HEATING SYSTEMS

ADVANTAGES AND DISADVANTAGES

When selecting a heating system, one should look at several factors such as initial cost, operational cost, maintenance, fuel supplies, and energy conservation. Each system has several advantages and disadvantages that should be considered.

Heat Pump ADVANTAGES of a heat pump are relative low cost of operation, when compared to standard electric heat; provides heat and air conditioning in same unit; it is flameless; and more Btus of heat per kilowatt-hour can generally be obtained with a heat pump than with resistance heating.

DISADVANTAGES of heat pumps are that they must be installed by experienced individuals, they tend to have high maintenance cost, and the initial cost of equipment and installation is relatively expensive. Vents and air return ducts take up space and, therefore, make installation in existing multi-story homes difficult. Also, individual room vents should not be shut off. (With any duct system do not shut off more than 25% of the vents at any one time.) With heat pumps thermostat set back at night or for short periods of time is not advisable. The greatest disadvantage of a heat pump, and for that matter all electric heating devices, is that electricity is not an efficient way to heat. By the time a fossil fuel is burned to produce steam and generate electricity, the efficiency has dropped below 50% meaning over half of the Btu output of the fuel is lost. Additional line and transformer losses through heat can reduce the efficiency to below 20%. Do not be mislead by the 100% efficient claim often used with electric heaters. They may produce heat from 100% of the electricity used but the electricity itself is not very efficient.

Electric Baseboard Heat ADVANTAGES of baseboard heaters are numerous: it is flameless, initial cost of equipment and installation is relatively low, maintenance cost is near zero (most have a life time warranty), and they provide individual room control if desired. Baseboard heaters are easy to install in remodeling jobs as well as new construction and they take up relatively little space.

DISADVANTAGES of electric baseboards are that duct work must be added if central air conditioning, air filtration, or humidity control is desired; furniture or draperies should not come in direct contact with units; and they require more double pole circuits which means a new electric panel may be needed in remodeling cases. Electric baseboards are a costly system to operate when compared to gas, oil, or a heat pump.

Electric Ceiling Heat ADVANTAGES of ceiling heaters are that they are flameless, relatively easy to install in both new and existing construction, they have low initial cost , low maintenance cost, and can be controlled in individual rooms if desired.

DISADVANTAGES are that repair of ceilings is more difficult if maintenance is required, people often complain of cold feet when sitting at a table, like baseboard heat ceiling units require more double pole circuits than other types of central heat, duct work is not available for other uses such as cooling and as with other electric resistance heaters it is costly to operate.

Electric Forced Air Heat ADVANTAGES are that duct work can be used for air conditioning, air infiltration and humidity control, they have relatively low maintenance cost, they are flameless, and have a relatively low initial cost for heating, air conditioning, air filtration, and humidity control.

DISADVANTAGES are high cost of operation, inefficient use of energy, does not allow individual room control, requires duct work which takes up space and, therefore, makes installation in existing multi-story houses difficult, and is a costly system when compared to gas, oil, or heat pump.

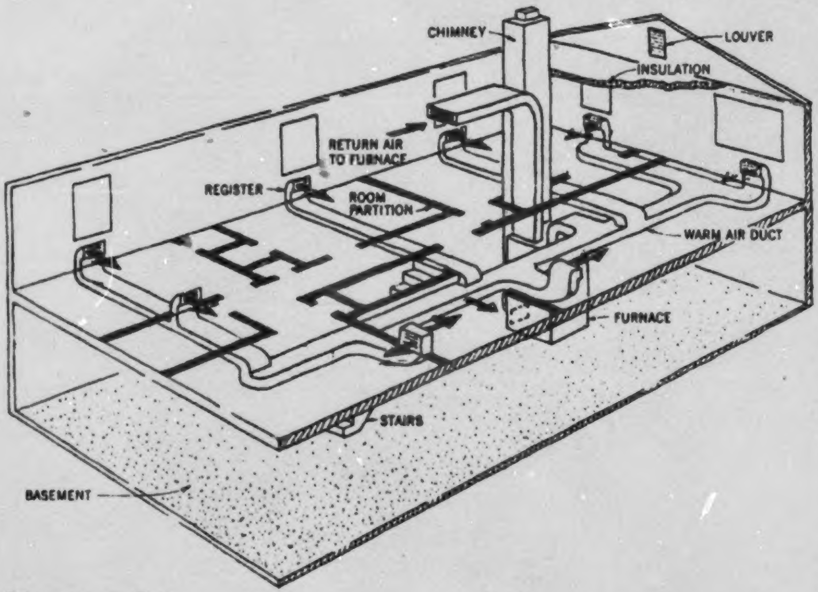


Figure 4.8
—Forced-warm-air systems are the most popular-type of heating systems. Most installations have a cold air return in each room (except the bathroom and kitchen). If the basement is heated, additional ducts should deliver hot air near the basement floor along the outside walls.

Oil/Gas Forced Air Heat ADVANTAGES are that oil and gas furnaces are relatively efficient in their use of energy, they are relatively economical to operate, and have moderate maintenance costs. Duct work can be used for air conditioning, air filtration, and humidity control; both are time tested systems which means there are usually adequate, competent servicemen to maintain the units; and the thermostat can be turned down at night for fuel savings.

DISADVANTAGES are that the units should have periodic servicing to maintain efficient operation, the initial cost of equipment and installation is high, and systems may be quite cumbersome and need a relatively large area for installation. Fuel storage is an added expense and is cumbersome with oil furnaces. If natural gas is not available, higher priced LP gas must be purchased. Installation in multi-story houses is difficult, and the homeowner must inspect and change filters when needed.

Hot Water Heat ADVANTAGES are that heating zones can be established to allow different temperatures to be maintained in different parts of a house. The piping that carries the hot water takes up much less space than duct work and can be routed with relative ease through existing walls and floors. This type of heating makes an excellent system for older, valuable homes where existing walls and styles are important and should be left as they are. The boiler should take up relatively little space and can

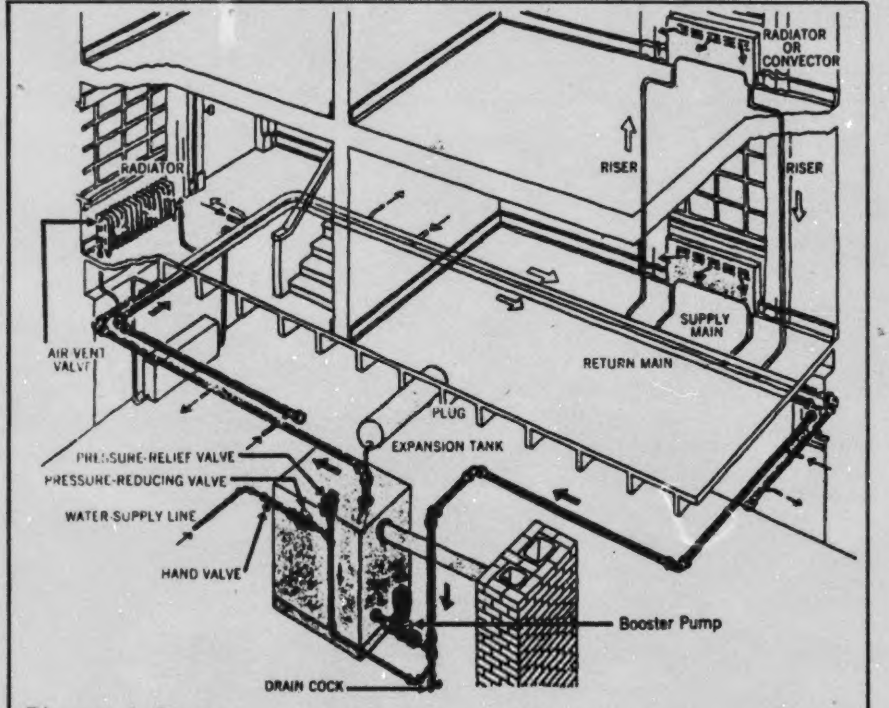

RADIATOR OR CONVECTOR
RADIATOR
RISER
RISER
SUPPLY MAIN
RETURN MAIN
AIR VENT VALVE
PLUG
EXPANSION TANK
PRESSURE-RELIEF VALVE
PRESSURE-REDUCING VALVE
WATER-SUPPLY LINE
HAND VALVE
Booster Pump
DRAIN COCK

Figure 4.9
—Two-pipe forced-hot-water systems have two supply pipes or mains. One supplies the hot water to the room heating units, and the other returns the cooled water to the boiler.

provide hot water for heating and for domestic purposes such as cooking, bathing, and washing. With proper pipe insulation the boiler unit can be located in an area away from the house. Baseboard radiators are designed to take up very little space and blend in with the base of the room perimeter. In addition, the thermostat can be turned down at night for fuel savings.

DISADVANTAGES of hot water heating are that duct work for central air conditioning must be added separately, the initial cost of equipment and installation is relatively high, a yearly maintenance schedule should be observed, leaking pipes can cause damage and a shortage of fuel (oil) is an added expense and potential problem.

FURNACE MODIFICATION

Proper sizing of the furnace and duct work is critical for efficient equipment operation. If the furnace is oversize, it will cycle on, heat up the house with a great rush of warm air, then shut off for a period of time, much too long for comfort. An oversize furnace wastes fuel and will not provide even, comfortable temperatures. Oversizing will most likely occur when a house has been weatherized and insulated sometime after the furnace was installed. Weatherizing in effect reduces the amount of heat needed and the furnace is then rendered much too large for comfort or efficiency. If a furnace of too small a capacity has been installed it will not maintain proper temperature control on a cold day even if it operates constantly. Both of these problems are serious and require professional assistance.

Generally there are two ways of dealing with an undersized furnace: reduce the heat load requirement of the house or replace the unit with a properly sized one. If the house has not been weatherized or insulated doing so will lower the heat loss and may bring the house down to a level that can be handled by the furnace. This is by far the best solution since it reduces energy consumption and in the long run saves money. Replacing the unit with a larger one does nothing for energy conservation it only makes the house more comfortable. The following article by Lyle K. Huhn reprinted from "Air Conditioning-Heating and Refrigeration News" (September 26, 1977) offers suggestions for adjusting home heating systems after adding insulation.

HOW TO ADJUST HOME HEATING PLANT AFTER ADDING INSULATION

Reprinted from
AIR CONDITIONING HEATING & REFRIGERATION NEWS
P. O. Box 2600, Troy, Mich. 48084

by Lyle K. Huhn

Among the many things that have been said in the past year about energy conservation is the idea that most residences should be treated to substantially reduce heat loss.

This means the maximum use of insulation and possibly adding storm windows and weatherstripping. Some homes have none of these things, some have completely adequate amounts, but most fall somewhere in between.

For years most experts in the heating field have believed that the best comfort results when the capacity of the heating plant matches the heat loss of the house at design conditions. Some will say that a little bit undersize is even better.

However, in practice, most heat plants were somewhat oversized at the time of original construction. If the heat loss of a house fell between two standard sizes, the next larger size was used, even if the heat loss was over a standard size by only two or three percent.

Enough consideration was not given to internal sources of heat in making a close call. Heat given off by kitchen ranges, water heaters, TV sets, lights, and small hand or counter appliances are completely useful in offsetting the heat loss.

If we now add insulation, storm windows, and weather stripping to a house, we either create a misfit between the heating plant and the house or make an existing misfit worse.

Therefore, a capacity adjustment needs to be made to the heating plant. Sometimes the reduction could be as much as 30% to 50%. It is necessary to make a new heat loss estimate and figure a new energy input.

The first reason for a capacity adjustment is to further save energy by increasing the efficiency, accomplished by not working the heating surface as hard so that more heat is extracted. The next reason is to improve comfort, which will be best when the heating plant runs all the time at design conditions.

There are several variations in types of heating systems. This article will consider only the major types of central systems. Methods of capacity reduction will vary with the energy source and the means of distributing heat throughout the house.

AIR AND HYDRONIC (WATER) SYSTEMS

Air systems and water systems offer great flexibility in capacity reduction because both of them have the capability of delivering heat to the individual rooms over a wide temperature range of the circulating medium. This similarity makes it possible to combine them in discussing methods, which will hold true whether circulation is forced or by gravity.

NATURAL GAS AS ENERGY SOURCE

When a contractor wants to start a program of capacity reduction, a suggested first step is to contact his local gas company to find out if it has a program organized to work with contractors on capacity reduction.

If so, it would be in the contractor's best interest to work with this program, get utility help, and conform with its policies. If the gas company does not have such a program, the contractor can set up a program of his own, using information herein as a guide.

On natural gas heating units it will be possible to reduce the gas input to 50% of name plate rating. Experience with high-low models, with the low step 50% has established this. The amount of capacity reduction needed will vary with the individual case. The new gas input should be set accordingly.

Most of these heating units will be equipped with an adjustable gas pressure regulator for the main burner. By adjusting this regulator to give a manifold pressure of 2 in. of water, a reduction of close to 20% will result. A manifold pressure of 2.5 in. of water will give a reduction of close to 10%. This will vary slightly with the exact manifold pressure required to give 100% of name plate rating.

A reduction in gas input of more than 20% will require a change in the orifice size. The new size should be figured on the manifold pressure that gave rating with the original orifice size. If that is not known, a manifold pressure of 3 in. of water is a good figure to use.

If a large reduction is made on a forced air system, it may be necessary to reduce the blower speed somewhat to avoid a feeling of cool air movement. Perimeter systems will not be a problem, but some other systems may.

PROPANE AS ENERGY SOURCE

On forced circulation water systems which are controlled so that a standby temperature is maintained in the heating unit, it is recommended that the standby temperature be set as low as possible.

Where propane is the energy source, the gas input should not be reduce more than 20% or 25% because of the risk of running into flashback problems. The orifice size must be reduced, and the manifold pressure kept at the standard figure of 11 in. of water.

OIL AS ENERGY SOURCE

If the oil is burned in a high pressure burner, and most of it is, capacity reduction is accomplished by using a smaller nozzle. The pressure should be maintained at rated value for the equipment, usually 100 psi. Full pressure is required to atomize the oil.

If a reduction of more than 25% is attempted, a smaller combustion chamber may be needed to keep the flame temperature up so combustion will be complete. The CO_2 and smoke readings will answer this question.

A possible need to slow down the blower to avoid a feeling of cool air movement should be considered. On forced circulation water systems set the standby temperature as low as possible.

ELECTRIC POWER AS ENERGY SOURCE

Most electrically heated homes were heavily insulated to begin with. Therefore the need for capacity reduction will not be encountered very often. Capacity reduction can be achieved by disconnecting one or more elements. Blower speed should not be reduced because the elements left in need the same amount of air to prevent overheating. Lower water standby temperature as much as possible.

STEAM SYSTEMS

Steam systems do not offer good prospects for capacity reduction. The boiler and its water content must be heated up to 212°F before the distribution of heat to the rooms can occur. A reduction in energy input of 10% to 15% should be attempted only on boilers of comparatively light construction and low water content.

Reducing the energy input does not require special materials or tools; it does not require special training. Therefore, it can be done now, and should be done now.

OTHER WAYS TO REDUCE ENERGY USE

If gas or oil is the energy source, additional conditions that waste heat need attention. For them, an immediate and simple solution is not sitting on the shelf waiting to be used. There is work to be done by the heating industry to develop a consensus on how to handle these problems. This will require discussion, debate, study, testing, and trial. Let us look at two situations.

RESTORING GAS/AIR RATIO ON GAS HEATING UNIT

Certain dimensions within the unit control the fuel/air ratio to obtain best results when the gas input is exactly at rating. When the gas input is reduced, there is room for more air to flow through the combustion chamber and flueways than is needed for combustion. This extra "unneeded" air is heated to flue gas temperature and goes up the vent, or chimney, thus creating a waste of heat.

It has been a tradition in the gas industry that changes in the basic dimensions of the combustion chamber and flueways are not to be made in the field. This practice has been carried on to insure that the original efficiency and safety of the unit would be preserved. However, to restore the proper fuel/air ratio after the gas input has been reduced will require a field change.

The industry needs new thinking to develop a solution to this cause of wasted heat. It should develop a consensus on the basic approach to the problem, the materials to be used, the skills and tools needed in applying them, and the training of manpower to do the job. The seriousness of the energy situation demands maximum effort.

DRAFT HOOD DILUTION AIR ON GAS HEATING UNIT

The purpose of the vent, or chimney, is to carry the flue gases to the outdoors. The amount of draft needed to do this does not balance out evenly. To be safe a little extra draft is needed. This pulls air from the house into the draft hood relief opening where it mixes with the flue gases and goes to the outside.

This dilution air is replaced by air leaking into the house from the outdoors. This air has to be heated up to room temperature, a waste of heat.

The amount of draft hood dilution air has never been under good control. When gas was plentiful and cheap this was not considered a serious problem, but today it is. The draft, and the amount of dilution air, depends on the size and height of the vent. It is much higher on two- and three-story houses than on one-story houses. It also depends on the outdoor temperature; it is higher on a cold day than on a mild day.

A further reason for not seriously working on this problem before is that it is a very complex problem; the cost will likely be high, possibly more than the savings will justify.

OIL: FUEL/AIR RATIO, DILUTION AIR

The high pressure oil burner has incorporated in its design a means of adjusting the fuel/air ratio when a change in the nozzle size is made.

The problem of too much chimney pull exists in oil-heated homes also. High draft opens a damper in the draft control and air is pulled from the house into the flue gas stream and goes to the outdoors. Replacement air from the outside has to be heated to room temperature, a waste of heat. This is the same basic problem as with gas. The mechanics are somewhat different, however, and the oil industry should work on this problem.

In the past the methods used to control the fuel/air ratio and to vent the flue gases to the outdoors have had a good safety record. In developing new methods in the interest of conserving energy, the overriding consideration must still be safety.

FURNACE MAINTENANCE[3]

Having heating equipment serviced by a reputable heating specialist before the start of each heating season could reduce fuel bills by as much as 10% and can save the discomfort and expense of equipment breakdown during the winter.

Several factors influence the efficiency of a heating systems and can be summarized as follows:

- properly adjusted burners
- clean nozzles and jets
- correct fuel pressure at nozzles and jets
- clean fuel filters
- clean air filters
- properly adjusted nozzle and jet openings
- correct size, supply and return-air ducts
- well lubricated furnace blower
- automatic (rather than manual) furnace operation[4]

If your furnace is fired by oil or gas, have the maintenance contractor clean the furnace and flue outlets, check the belt for tension and wear, oil the motor and fan bearings (if they are not sealed), change or clean the filters, check combustion and safety devices, and make other adjustments or tests recommended in your owner's manual. An efficiency test should be made to make sure the furnace is operating at peak efficiency.

For gas furnaces, the pilot light should be checked for a clean, blue flame and the sensing unit cleaned.

There are several things you can do to keep your furnace running efficiently. Check furnace filters every two months during the heating season; clean or replace them as needed. Clean the fan blades annually. Keep the area around the furnace housing free of dust, lint, and litter.

Learn to recognize trouble signals: odors, soot at the burner, black smoke rising from the chimney, or surging water in a boiler guage indicate malfunction or improper adjustment. Get professional assistance.

An electric furnace requires little maintenance. Follow the manufacturer's recommendations.

If one area of your home gets more heat than it needs, or if some rooms become hot before others are even warm, your heating system probably needs to be balanced. Have this done by a heating service specialist.

If you have a hot water baseboard heating system, consider adding thermostats, valves, and piping to provide zone heating for several areas.

DUCTS and PIPING [3]

Inspect heating ducts annually for leaks and repair them with a quality duct tape.

Heating ducts and water or steam pipes that pass through unheated--attics, crawl spaces, and basements--should be covered with duct insulation or unfaced R-11 insulating batts or blankets. If the ducts are used for air conditioning as well as heat, use faced insulation and place the vapor barrier on the outside to prevent condensation on the duct.

Because they are integral parts of your heating system, registers and radiators require special care and attention.

Dust on radiators, convectors, baseboard heating units or in ducts acts as insulation and wastes heat. Vacuum regularly.

Concentrate heat where you need it: living areas, bathroom, and study areas.

Lower temperatures in the kitchen, bedrooms, and less active areas. If your home is equipped with zone heating (more than one thermostat), reduce the temperature in these areas.

Adjust hot air registers or the control louvers on hot-water baseboard systems to satisfy your heating needs. If your registers are not adjustable, consider replacing them.

Bleed air from hot-water system radiators annually: open each radiator valve, hold a cup under it, and keep it there until water comes out. Don't drain the water; you need only to remove the air, which inhibits water circulation.

For the best performance, paint radiators with a special radiator paint. Metallic paints and casings built around radiators reduce heat transfer as much as 25%. Install a sheet of metal or aluminum foil behind radiators near cold walls so that heat will be reflected into the room.

Don't block air inlets and outlets, including radiators, with furniture, draperies, or clothing.

HEATING with WOOD

In recent times the U.S. has moved away from the use of wood as a fuel. We are dependent instead upon the fossil fuels, oil, gas, and coal, and the electricity they produce to heat our homes. But there are many individuals and groups who advocate a shift back to wood as a heat source not only because it is renewable but also because it is abundant in most parts of this country. It is interesting to note that approximately 90% of the people in developing countries use wood as their primary fuel. This overdependence upon wood has caused deforestation and considerable ecological damage when it has been uncontrolled. In the U.S. wood waste and under utilization prevails. Forest land actually benefits from selective cutting and this should be part of a good management process. It is anticipated that as the cost of fossil fuels increases the use of wood will become a viable alternative and indeed many people have already turned to wood as a heat source. According to Burning Wood,[5] wood is an economically competitive fuel if it can be:

- Efficiently prepared for use with a minimum of handling.
- Obtained as a result of properly managed home woodlands.
- Cut in advance (at least 6 to 10 months) to season properly.
- Burned in a properly designed heater.

Burning Wood also lists several disadvantages to wood as a fuel. They are:

- Cutting, hauling, and stacking is hard work and can be dangerous.
- The fire must be periodically tended and ashes must be removed.
- Wood must be seasoned or dry for best performance.
- Stove pipes and chimneys need periodic cleaning to remove soot and creosote. (This will be discussed in detail later in this unit).
- Wood is relatively bulky for the amount of heat derived compared to coal and oil so a large storage area is needed.

All these disadvantages may be outweighted, though, by the independence and self-reliance afforded by providing one's heat with wood.

FIREPLACES

Although aesthetically pleasing and very popular in modern homes, the fireplace is a very poor heater. A typical masonry fireplace can have an efficiency of -5 to 15%. This means that in some cases more heat is drawn out of the house through the chimney than is replaced by the fire. At best, the typical fireplace will only supply 15% of the heat potential of the wood being burned. There are a number of remedies that will help to improve fireplace efficiency although none will make a fireplace as efficient as a good wood stove or a conventional furnace. Some of these are:

- A damper, glass doors, asbestos board, or sheet metal covering to close off the fireplace when the fire is dying down or has gone out. This will prevent the "chimney effect" from continuing to draw warm air out of the house even when the fire is out.
- Tube or recirculating grates that heat room air by passing it through tubes on which the fire is built.
- Installing an outside duct for fireplace combustion. This vent should open directly in front of the fire and draw cold air from outside. This will prevent much of the air infiltration that occurs when a fire is burned and will raise the efficiency of the fireplace.
- Prefabricated circulating fireplaces that provide separate combustion air and heated room air. Even these units are not as efficient as a well-designed air-tight wood stove and in fact most are only about 30% efficient at best.

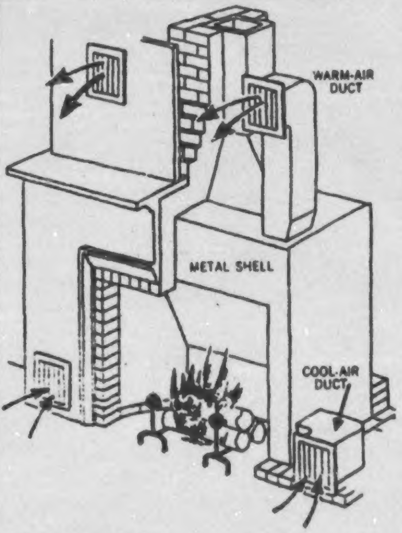


Figure 4.10

.—Modified fireplaces heat more efficiently than ordinary fireplaces. Cool air enters the inlets at the bottom, is heated by contact with the warm metal of the fireplace, rises by natural circulation, and is discharged through the outlets at the top. The outlets may be located in the wall of an adjacent room or a second-story room.

- There are devices designed to increase heat out-put by holding logs in a position which enables a larger hot area to be exposed, therefore giving off more radiant heat.

ADVANTAGES AND DISADVANTAGES OF FIREPLACE.[2] The advantages of fireplaces are that they provide a back-up heating system in case the central system fails, they add esthetic value to the living area of the home, and they increase the resale value of the house. A fire in the fireplace adds warmth on unseasonably cool days without the use of central heating. Fireplaces can be used to heat one or two rooms of a house (practical only when central heat sources are eliminated from the areas adjoining the fireplace). Heat efficiency can be increased by using factory made metal fireboxes that allow air to be circulated around them and out into the room. (See Figure 4.10).

The major disadvantage with fireplaces is that they are an inefficient method of heating. Also, the damper must be kept-closed when a fire is not burning and unless glass doors are installed it will actually draw existing warm air out of the room until such time as the chimney can radiate enough heat to increase the room temperature. Wood storage is a problem. Wood that must be purchased for burning in a fireplace is an extremely expensive source of heat and ash removal can be a bother if the fireplace is used constantly. A fireplace must be constructed properly or smoke will enter the room rather than up the chimney, and it takes up living space if constructed on an inside wall. However, a fireplace has a tendency to be less expensive and more efficient if built on a inside wall. If andirons or a grate are not used and a log bed is not properly made, a fire hazard may develop. Faulty chimneys can also be a fire hazard.

WOOD STOVES

Wood stoves are devices which control the rate of combustion by being as air tight as possible. The efficiency is lowered if air other than that introduced through air inlets is allowed to get in. Air tight wood stoves (not to be confused with less efficient pot belly or franklin stoves) can be as high as 70% efficient with the average around 50 to 60%. This gives the wood stove an obvious advantage over fireplaces.

The different types of wood stoves are illustrated in Figure 4.11. They include kitchen, parlor, box, fireplace, pot belly and different configurations of air-tight stoves.

Wood stoves are built of one of three basic materials: sheet metal, plate steel, or cast iron. Sheet metal stoves are thin, lightweight, and generally inexpensive. They heat up quickly but

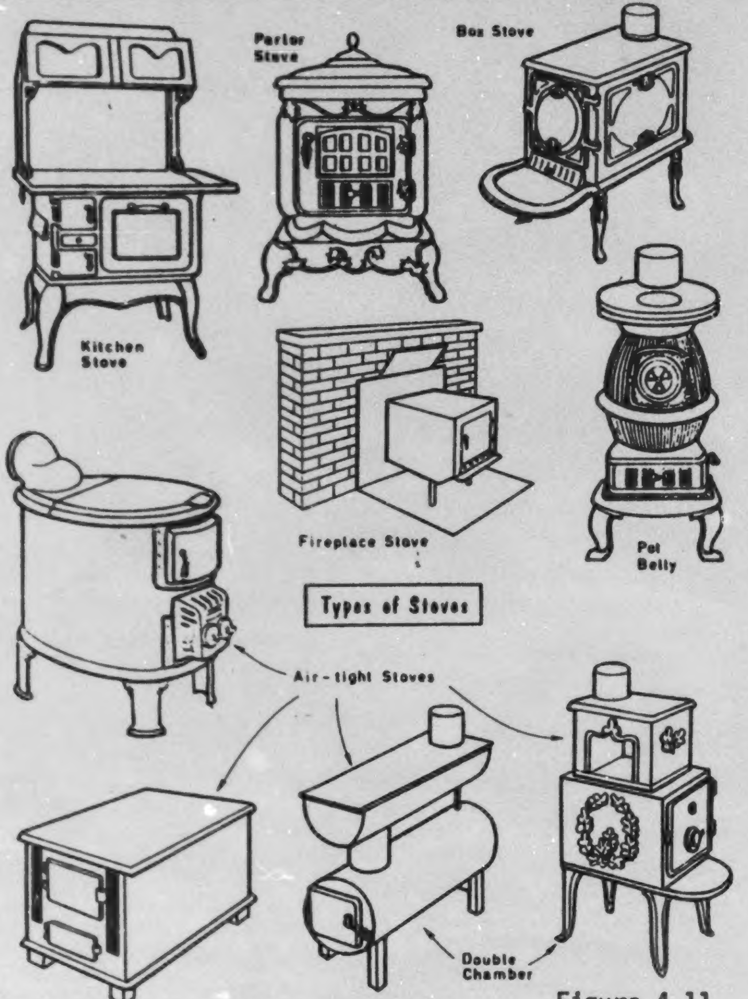


Figure 4.11

because the metal is thin they do not have the longenity of heavier stoves. An example of a sheet metal stove is the Ashley. Welded or plate steel stoves are made of steel plates approximately 1/8" to 1/4" thick. They are often firebrick lined and are very heavy. Always inspect the welds on this type of stove since this is the stress point and the most likely place for failure. An example of a plate steel stove is the Fisher. Cast iron stoves are the oldest type of metal stove. They are expensive, long lasting, and heavy but have a tendency to leak around the seams if the cement has deteriorated. The cement should be inspected and replaced periodically. Also a cast iron stove should be seasoned very carefully for the first month to prevent cracking. An example of a cast iron stove is the Jotul.

DRAFT An important factor in wood stove efficiency is the draft configuration. The draft configuration shown in Figure 4.12 are used to increase the flame path and burn the volatile gases, raising efficiency.

WOOD FURNACES The wood burning furnace is similar to a woodstove in that it is air-tight and controls combustion but it can

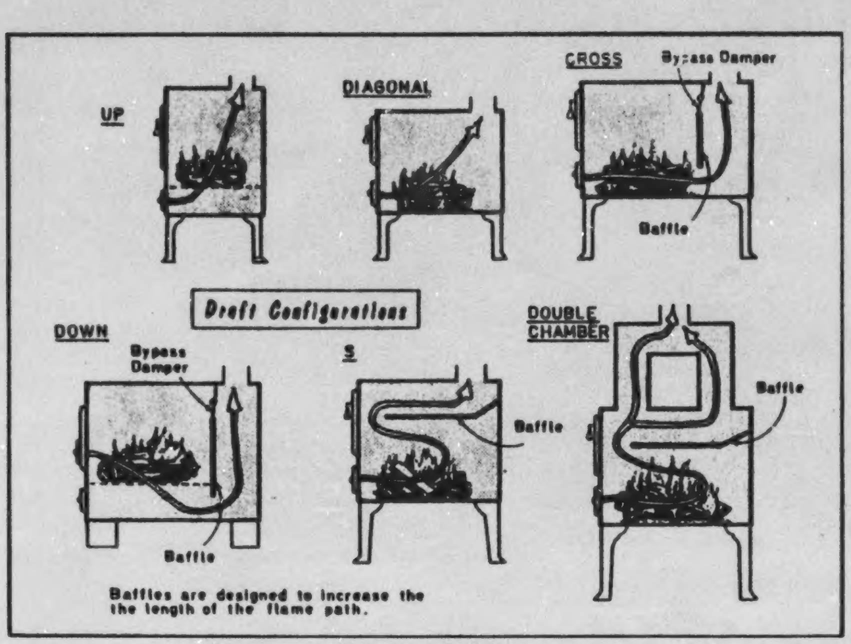

UP
DIAGONAL
CROSS
Bypass Damper
Baffle
Draft Configurations
DOWN
Bypass Damper
Baffle
S
Baffle
DOUBLE CHAMBER
Baffle
Baffles are designed to increase the the length of the flame path.

Figure 4.12

also be used with a forced air or hot-water system. Most wood furnaces are thermostatically controlled and accept large amounts of wood. They can be equipped with oil, gas, or electric backup to maintain the temperature even if the fire dies out.

STOVE INSTALLATION   It is essential that wood stoves be properly installed and operated. Minimum installation clearances have been established by the National Fire Protection Association (NFPA) and should be adhered to when positioning a wood stove. Figure 4.13, 4.14 and 4.15 show minimum clearances, and the proper method for passing a stove pipe through a wall.

Minimum Clearances from Combustible Walls and Ceilings*

Type of Protection	Stove Type		Stove Pipe
	Radiant	Circulating	
None	36"	12"	18"
1/4" Asbestos Millboard, spaced out 1"	18"	6"	12"
28 gage sheet metal, spaced out 1"	12"	4"	9"
28 gage sheet metal on 1/8" asbestos millboard, spaced out 1"	12"	4"	9"

*From National Fire Protection Association No. 89M, 1971.

For maximum heat distribution the following ideas should be employed when installing a stove:6

1. Choose as central a location as possible. Stoves will be most efficient in delivering heat if located near the center of the areas to be heated.

2. Placement near stairs will greatly assist in heating areas above. Vertical distribution is natural since warmer air rises.

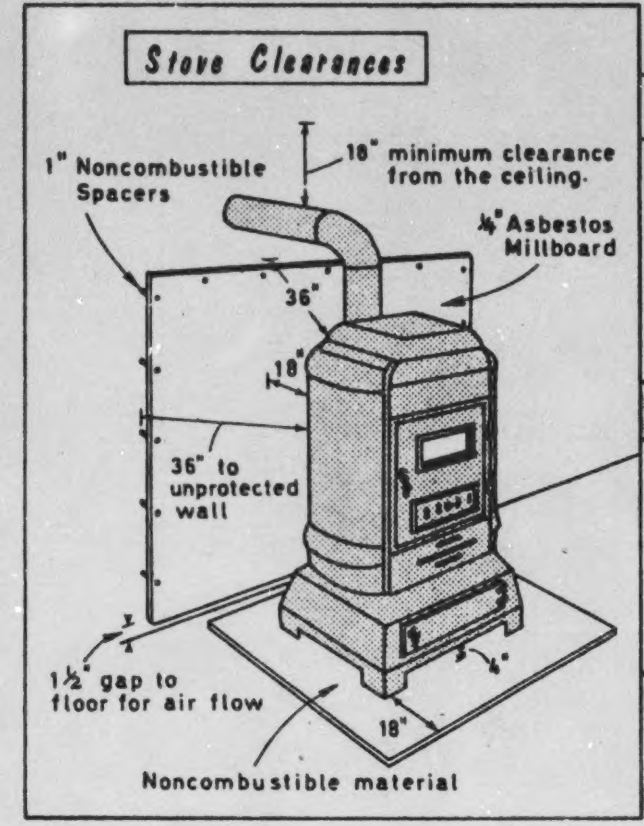
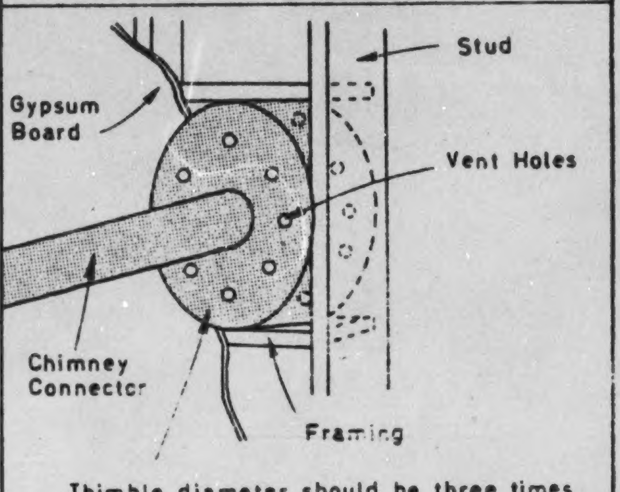

Stove Clearances
1" Noncombustible Spacers
18" minimum clearance from the ceiling.
¼" Asbestos Millboard
36"
18"
36" to unprotected wall
1½" gap to floor for air flow
18"
6"
Noncombustible material

Figure 4.14

A ventilated thimble permits the stove pipe to pass safely through a combustible wall.


Stud
Gypsum Board
Vent Holes
Chimney Connector
Framing

Thimble diameter should be three times the diameter of the stove pipe.

Figure 4.15

3. Heated air at the ceiling cannot easily pass under the tops of doorways and installation of a register at these locations will greatly aid lateral air movement.

4. Installation of registers through the ceiling will provide an upward current of warm air and-help heat the areas above.

5. Use of the fan in the central heating furnace may be very useful in getting stove heat to all locations in the house, especially if the stove itself or a significant portion of its heat output is near the cold air return register.

6. Do not locate the stove in the basement unless you want to heat the basement! The largest-component of radiant heat (two-thirds of the total) will be directed toward the walls and floor of the basement where it will do little or no good.

FIREWOOD SELECTION

An important part of getting the most from a wood burning stove is the selection and preparing of firewood. Firewood should be cut at least 6 to 9 months prior to burning to allow time for it to dry out. Splitting reduces the drying time and makes the wood easier to handle and burn. Firewood should be properly stacked to facilitate drying and should be covered while still allowing air circulation. Seasoning should last for several months and will reduce the moisture levels in the wood making for higher heat output and easier burning. The manual measurement units for firewood are illustrated in Figure 4.16.

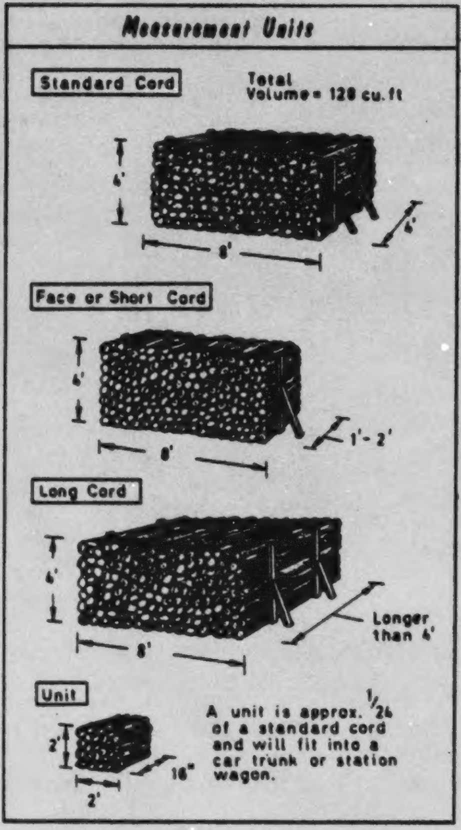

Measurement Units
Standard Cord
Total Volume= 128 cu.ft
4'
8'
4'
Face or Short Cord
4'
8'
1'-2'
Long Cord
4'
8'
Longer than 4'
Unit
A unit is approx. 1/24 of a standard cord and will fit into a car trunk or station wagon.
2'
2'
16"

Figure 4.16

The type of wood used also affects the amount of available heat. This is because some wood is denser and heavier than others and, therefore, gives more Btus per cord. The Btu output of all wood is the same per pound: 8600 for dry, 7000 at 20% moisture, and 4300 at 50% moisture. One hundred pounds of pine will provide the same amount of Btus as one hundred pounds of oak. Common woods are shown in Table 4.I.

Species	Heat Value	Ease of Splitting	Smoke Production	Popping & Sparking*	Overall Rating
HARDWOODS					
Ash, Red Oak, White Oak, Birch Hickory, Hard Maple, Beech	high	easy	low	low	excellent
Soft Maple, Cherry, Walnut Sassafras, Locust	medium	easy	low	low	good
Elm, Sycamore, Gum	medium	difficult	medium	low	fair
SOFTWOODS					
Yellow Pine, Douglas Fir	high	easy	high	low	good
White Cedar, Red Cedar	medium	easy	medium	high	good
White Pine, Ponderosa Pine	low	easy	medium	low	fair
Spruce	low	easy	medium	high	poor

Table 4.I

CHIMNEY CLEANING[7]

More and more people are heating their homes with wood in order to supplement or, in some cases, replace more conventional fuels such as fuel oil, propane, or natural gas. One unfortunate result of this switch to wood has been a dramatic increase in the number of chimney fires in most areas.

When wood burns, the combustion process is never absolutely complete. The smoke usually contains unburned gases and a substance called creosote. This creosote will condense out of the flue gases on to cooler surfaces of the wood burning system from the inside of the stove to the top of the chimney. One figure commonly used for condensing temperature is 250°F. That is when the creosote will condense on the surfaces. Creosote is usually dark brown or black in color and has an unpleasant odor. Its actual chemical composition is not well known because it is a very complex mixture of compounds.

At very low temperatures, below 150°F, the creosote deposit will be quite fluid in nature. As these deposits are warmed they coagulate and form a sticky tar-like substance which, when very hot, will ignite causing chimney fires and the danger of home fires.

The amount of creosote condensing on the surfaces of the system varies according to the density of the smoke, the temperature of the surface, and the type and d ness of wood being burned. Dense smoke from a smoldering fire carries the most unburned creosote.

Unfortunately, creosote problems are most effectively reduced by reducing the efficiency of the heating system. Air circulating in the stove causes more complete combustion and more heat escaping up the chimney--which heats the chimney to prevent creosote buildup. However, these conditions rob the room of much of the heat from the fire. Therefore, creosote problems are more severe in the newer more efficient stoves than in leaky or open stoves or conventional fireplaces. In other words, the more efficient stoves deliver a larger amount of heat to the room, therefore reducing temperature in the stove pipe and chimney. This reduced temperature also increases the chances of creosote deposits.

Combustion of creosote deposits is likely to occur during a very hot fire. Chimney fires are very intense, roaring fires which produce flames and sparks that shoot from the top of the chimney. Chimney fires weaken the masonry in the chimney, can create fires on the roof surfaces, and are not considered a safe way to remove creosote from a system. A chimney fire is most effectively controlled by eliminating air, by closing all dampers to the stove and chimney flue. Other methods such as a mist spray of water, salt thrown on the fire, and a fire extinguisher have also been used to stop a chimney fire.

One of the more effective methods suggested to reduce creosote build-up is to deliberately have a hot fire for perhaps 15 to 30 minutes each day. This hot burning fire tends to "burn off" the creosote in very small amounts each day thus eliminating build-up problems.

Stove pipes and chimney flues should be periodically inspected for creosote build-up. One effective method for checking stove pipes is to simply tap on the exterior of the pipe with a metal object. The sound will change from a metal ping to a dull thud as materials build up inside the pipe. Inspection of the chimney may take place from the roof or in some cases it is effectively done by the use of a mirror used to look up through the chimney flue. Inspection of stove pipes and chimney flues should be done frequently, especially during the first wood burning season. Some people have cleaned their chimney and stove pipes as frequently as once a month. Such frequent cleaning is not necessary in most cases but frequent inspection is certainly recommended. Professional chimney sweeps are becoming common in many areas. Current rates for cleaning are in the range of $30 - $50, depending on size, style, and other factors related to your chimney set-up.

There are several methods commonly mentioned for the do-it-yourself approach to cleaning chimneys. There are several chemicals on the market which claim to clean a chimney simply by dumping the substance onto the fire. At this point there is considerable controversy as to just how effective such chemicals are. Some state fire marshals don't approve them as they may produce intense heat in the stove, causing possible damage.

Mechanical cleaning methods, sometimes suggested, generally involve some sort of scraping device to remove soot and creosote build-up. Commercial brushes and metal scraping devices are being marketed. Homemade devices such as burlap bags filled with chains, packing wires, or bricks may also be capable of doing the job. Some provision must be made inside the house to control the spread of soot and dust. A plastic bag may be taped over the end of a free standing fireplace or a cover placed over the opening of a wall fireplace.

Some words of caution are worth mentioning to the potential do-it-yourselfer. Be sure you are capable of handling the task of getting on the roof and making yourself secure. Do you have a sturdy ladder, someone to assist you, etc.? Be advised that some prefab metal chimneys can be damaged if the wrong type of cleaning mechanism is used. Loose mortar and other signs of wear in masonry chimneys may indicate the need for professional repair.

It should be recognized that even with the most conscientious cleaning habits the owner of the wood stove still faces some danger of fire; formation of creosote is a natural process resulting from the burning wood. However, properly installed wood burning stoves and properly constructed chimneys will withstand occasional chimney fires. Everything possible should be done to reduce the frequencies of such fires.

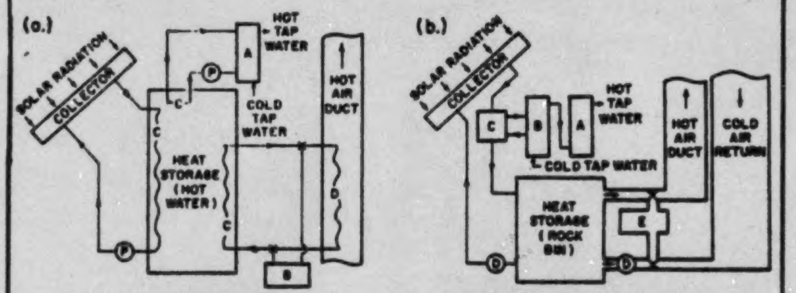
SOLAR ENERGY

There has been ever increasing talk lately of using the sun for home heating. There are those who claim that solar heating systems are impractical and expensive, and that solar has no future because it cannot be used for large scale production of electricity. A realistic appraisal of solar, however, will show that the real potential is for heating houses directly. The beauty of this is that the individual can develop and use a solar heating system independent of outside influences such as fuel prices and utility company control. By using the sun to heat one's house, one is far less dependent upon non-renewable resources, such as gas or oil, and can take a step toward self reliance and the security it brings.

The use of solar energy is not a new concept. The sun has been used for centuries for water and space heating in all parts of the world. However, for many years the price of fossil fuels has been so low that there was no reason, in economic terms, to not use it. Recent events such as the oil embargo of 1973-74, the Three Mile Island nuclear accident and the realization that fossil fuels (oil, coal and natural gas) are being depleted at an alarming rate have focused much attention to solar energy as a viable source of energy for the present and certainly the future. Also, with energy prices going up every day and likely to rise even higher, solar energy is becoming an increasingly attractive and competitive alternative energy source for residential space and water heating. Of equal importance, solar energy systems are nonpolluting and ecologically harmless, and the sun's power is inexhaustible.

Active Solar Solar energy systems are divided into two categories: active and passive. Active systems are divided into two types: liquid, which uses a fluid to transfer heat from a collector to storage, and air which uses air to transfer the heat. Both liquid and air systems use pumps and pipes, or fans and ducts to carry heat from the collectors to storage and from storage to the living space of the house. Active systems can be incorporated into new and existing houses and in many cases can share the air conditioning equipment already used with a conventional heating system (Figure 4.17).

The advantages of a water or liquid system are they hold and transfer heat well, water can be used as storage, they can be used to heat and cool houses, and they have compact storage and small conduits.



A. CONVENTIONAL WATER HEATER
B. CONVENTIONAL FURNACE
C. HEAT EXCHANGE-LIQUID TO LIQUID
D. FAN COIL HEAT EXCHANGE-LIQUID TO AIR
P. PUMP

A. CONVENTIONAL WATER HEATER
B. SOLAR HOT WATER STORAGE
C. HEAT EXCHANGE-AIR TO LIQUID
D. BLOWER
E. CONVENTIONAL FURNACE

Figure 4.17 SOLAR SPACE HEATING AND DOMESTIC HOT WATER SYSTEMS: (a.) FLUID SYSTEM (b.) AIR SYSTEM

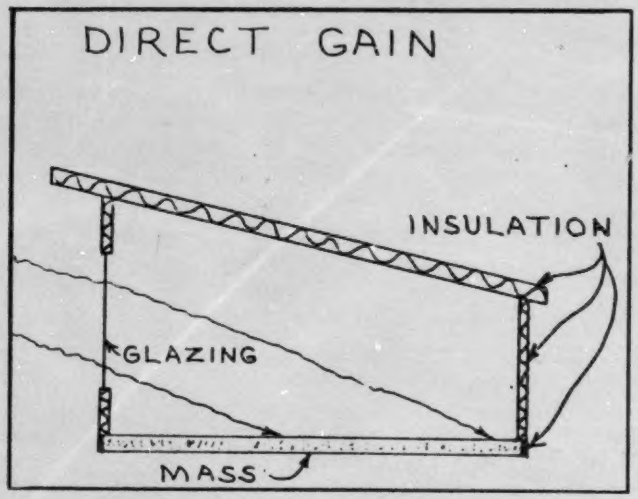
Leaking, freezing, and corrosion can be a problem with water systems. Corrosion inhibitors are needed with water when using steel or aluminum. These non-corrosive and non-electrolytic liquids are toxic and some are flammable. Water systems must be protected from freezing by antifreeze solutions or by a drain down feature. Caution must also be exercised when using a liquid collector for heating domestic water. A leak in a system using toxic, poisonous, non-corrosive or antifreeze materials could be dangerous.

Air systems tend to be moderate in cost, have no freezing problems, and no boiling or pressure problems. Minor leaks are of little consequence and, because the air is used directly to heat the house, there are no temperature losses due to heat exchangers.

On the other hand, although air can be used to heat a house, it cannot presently be economically adapted to cooling. Large air ducts are needed, and a larger storage space is needed for rocks or pebbles. Also, heat exchangers are needed if the system is to be used for heating water.

Passive Solar The other method of using the sun to heat a house is passive solar heating. In passive solar heating, the sun's energy enters a building, is sometimes stored for later use, and heats the building without the use of fans, pumps, or other mechanical devices. The warmth moves by natural means-conduction, convection, and radiation. Examples of passive solar designs include:

Direct Gain - the sunlight enters the house's south-facing windows and is absorbed and stored in heavy materials in the building. These heavy materials, such as a concrete slab floor, then reradiate the heat into the house as the interior temperature drops. The addition of insulated shutters or shades will prevent the loss of heat through windows at night.



Thermal Storage Wall - or Trombe wall is a large heavy wall placed behind the windows on the building's interior. House air is heated by circulating between the wall and the windows.

Sunspace or Isolated Gain - uses a porch or greenhouse to provide heat for the house. The greater the mass the more effective this type of system is.

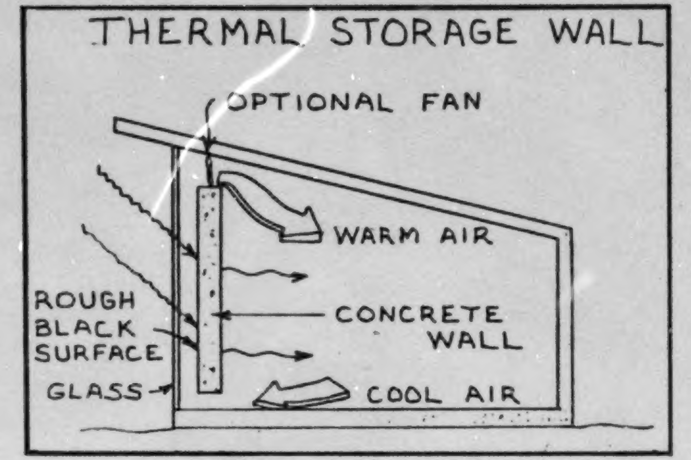

THERMAL STORAGE WALL
OPTIONAL FAN
WARM AIR
ROUGH BLACK SURFACE
CONCRETE WALL
GLASS
COOL AIR

Figure 4.19

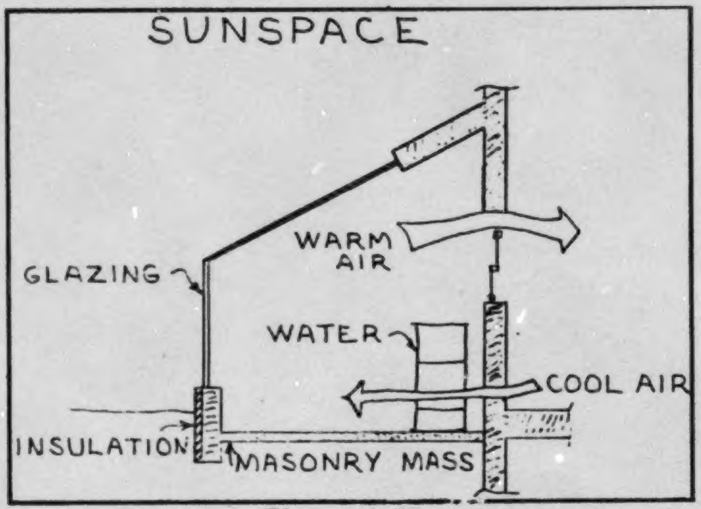

SUNSPACE
WARM AIR
GLAZING
WATER
COOL AIR
INSULATION
MASONRY MASS

Figure 4.20

PLANNING FOR A SOLAR HEATING SYSTEM[8]

Consider the following points when planning a solar heating system - either active or passive:

1. House is weatherized and well insulated.
2. New or existing house has a design which allows additions or modifications.
3. Orientation to a southern exposure and adequate space for a collector.
4. Collector site (or house itself in passive systems) is free of shadows from buildings, terrain, and vegetation during heating season.
5. Local zoning and building codes that allow the system design.
6. A climate that justifies using the system.

Before deciding on any solar heating system, active or passive, investigate all options carefully. Read, question, and talk to people who are already using solar heating in your area. A little research now can pay off handsomely in the future.

unit 5

ENERGY and HOME APPLIANCES

by: J. Sinn

Energy use for appliances and hot water consume from 10-25% of the energy used in most households. Even though each appliance may consume only a small portion of this energy, the accumulated effect of conservation from all appliances can be significant and should be encouraged. Care should be taken when appliances are purchased to insure that they are as energy efficient as possible. Proper operation and maintenance will also add to energy savings potential.

Home Energy Conservation Primer

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Energy Use In Home Appliances

Energy is used by home appliances in four basic ways: heat production; mechanical motion; heat expulsion; and electronics application. Some appliances use a combination of these ways to perform their prescribed function. Before examining the efficient use of energy in home appliances, it is necessary that a general understanding of their operation be achieved.

HEAT PRODUCTION

Of all home appliances, those which are heat producing consume by far the largest amount of energy. These appliances include, for example, the hot water heater, range and oven, clothes dryer, as well as an assortment of other minor appliances. An understanding of heat producing appliances should begin with the measurement of heat energy.

The BTU (British Thermal Unit) is a standard measure of heat energy. The BTU, or in other words, a unit of measure for heat quantities. The BTU is defined as the amount of energy required to raise the temperature of one pound of water one degree fahrenheit which is approximately equal to the amount of the heat produced by one wooden kitchen match.

Heat producing appliances, with the exception of microwave, function primarily through heat transfer to some object which must be cooled or dried. Heat is transferred from the source to the object. By three methods: conduction, convection and radiation. Conduction is the transfer of heat from one part of an object to another part of the same without any reactive displacement of the parts of the object. Convection is the movement of air and heat caused by warm air rising and cold air sinking. Radiation refers to the transfer of heat through space by wave motion.

Heat is produced in home appliances by three sources: gas, resistance electric, and microwave. The heat source used depends on the appliance.

Gas There are two types of gas used in the home, natural gas and LP (liquified petroleum). Natural gas is the most commonly used type and is formed by decaying organic matter in the absence of sufficient oxygen. Our traditional source of natural gas is obtained by drilling underground wells to reach gas produced millions of years ago. However, some natural gas is now produced directly from organic matter, though as yet not on a commercial scale. Natural gas is a combination of carbon and hydrogen ions with a formula CH_4. Chemical energy stored in the carbon-hydrogen bonds is released in the form of heat and light by combustion. The heat in values of natural gas averages 1031 BTU per cubic foot.

LP or liquified petroleum gas is either propane ($C_3 H_8$), buthane ($C_4 H_{10}$), or a combination. It is quite similar to natural gas, but has a higher heat content (between 2500 and 3175 BTU/cu. ft.). Many appliances can function adequately on LP gas (dryer, stoves, furnaces, etc.). However, the cost of LP gas is usually greater than equivalent energy forms (although the comparative cost could change, depending on availability of energy forms and other factors) and thus, may not be an acceptance alternative. LP gas can be an acceptable energy form where other energy sources are not readily available (camping, rural living, etc.).

Electric Electricity causes heat through a flow of electrons. The opposition to the flow of electrons is called resistance, and the resistance causes heat. In the home, electricity is carried through copper wires (low resistance) except where its purpose is to create heat. Heating elements, or electrical conductors with high resistance are usually thin wire of nickel chromium or some related allow. The elements may or may not be covered by an insulator, depending upon their intended use. An example of electric resistance heating is shown in Figure 5.1 & 5.2. The diagram is of an electric cooking element as one would be on a stove.

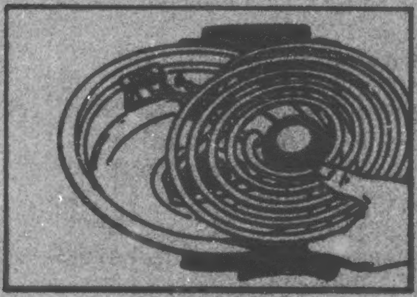


Figure 5.1 (Peet)

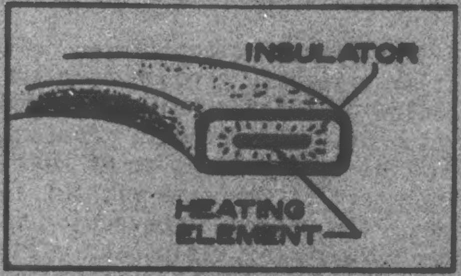


Figure 5.2 (Koff)

Microwave Another way to produce heat is through the generation and direction of microwaves. Microwaves are part of the electromagnetic spectrum, which also includes x-rays, visible light, and radio waves. As with light waves, microwaves may be reflected, transmitted, or absorbed, depending primarily on the molecular structure of the material they come in contact with. Metals (such as aluminum foil) reflect microwaves; glass, paper and most plastics transmit them; and food and liquids absorb microwaves. When microwaves are absorbed, the modecules of the absorbing material move, creating friction and thus heat. The movement of the molecules is the action necessary for the cooking of food.

Mechanical Motion

Electric motors used in home appliances are of two basic types, universal and induction. The universal motor contains brushes which touch the rotating part of the motor and transfer current directly to it. The major advantage of the universal motor is that it can adapt to the size of the load put on it, slowing down under a heavy load. Universal motors are used in small appliances such as mixers and sewing machines. They may operate on alternating or direct current.

Induction motors (Figure 5.3) move by means of a transfer of energy induced by the generation of a magnetic field created by electricity passing through coiled wires. The advantage of induction motors is that they tend to maintain a constant speed. Induction motors operate on alternating current only and are used in care appliances such as washers, dryers, and dishwashers.

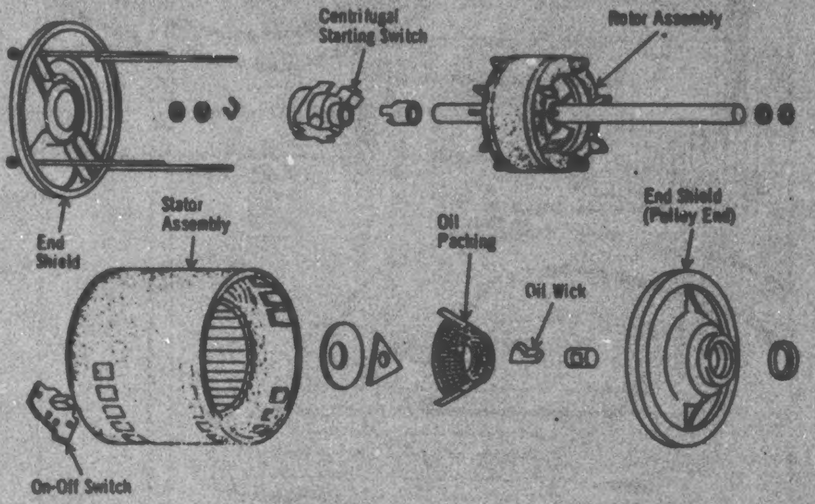


Figure 5.3 In the a-c induction motor, there are usually no electrical connections made to the rotor by brushes as in synchronous and d-c motors. Therefore, this motor has long trouble-free service and is most widely used of all a-c motors (Mileaf)

Heat Expulsion

Heat expelling appliances (refrigerators, freezers, and air conditioners) all have the same basic function and internal design. The physical principle involved is that when a chemical change state (solid--liquid--gas), energy is exchanged with its surroundings. In the particular case of heat expelling appliances (heat pumps included) it is the liquid--gas change that is involved. The refrigerant most commonly used is dichlorodiflouromethane, or R-12, a relatively harmless substance which has a boiling point of -21.6°F.

The refrigerant circulates through the appliance, changing from a liquid to a gas in the cooling compartment, and absorbing heat which consequantly lowers the temperature of the compartment. As the refrigerant continues its circulation through the appliance it goes to the condenser where it changes state back into a liquid. Here the heat, which was absorbed from the cooling compartment, is released. In the case of an air conditioner, the cooling compartment is the house, and the heat is released to the outside. (See Figure 5.4).

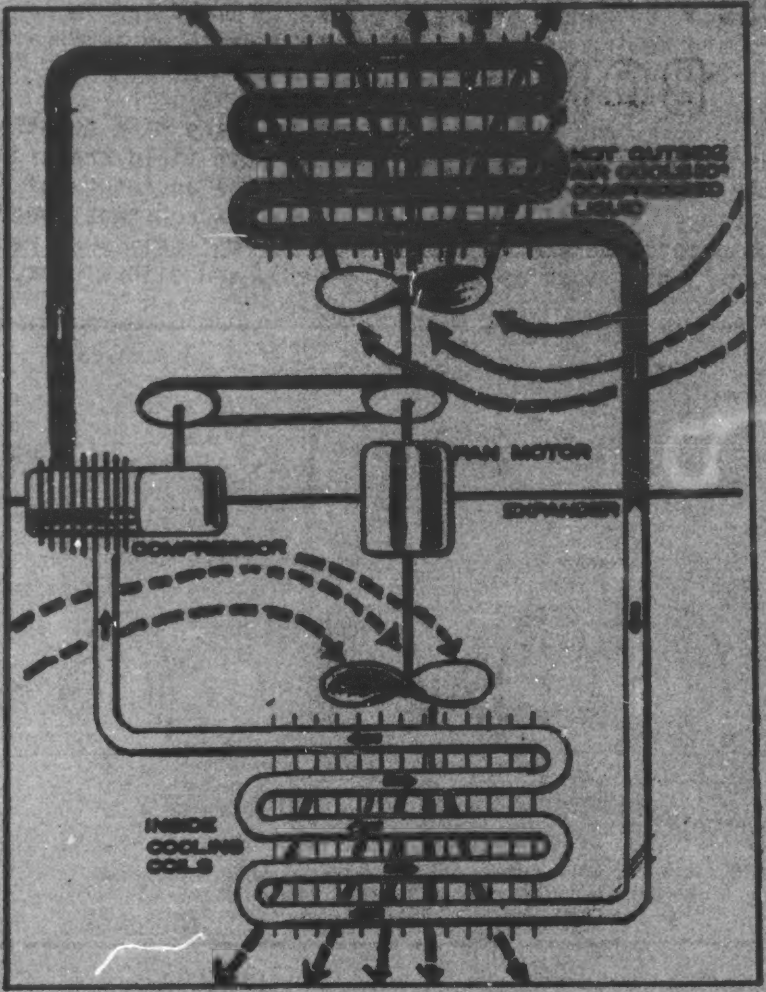

HOT OUTSIDE
AIR COOLS
COMPRESSED
LIQUID
FAN MOTOR
EXPANDER
COMPRESSOR
INSIDE
COOLING
COILS

Figure 5.4 (Koff)

Electronics

Electronic devices are being used in televisions, radios, washers, dryers, ovens, sewing machines and many other home appliances. Semi-conductors are the main component in electronic devices. The semi-conductors are used to control the flow of electric current.

Due to their simplicity, electronic devices provide effective controls for appliances in an energy efficient manner.

GENERAL APPLIANCE INFORMATION

When considering appliance energy conservation, it is important to remember how most energy is used in the home. Table 5.A shows the amount of energy used in the home. The bulk of home energy (65%) is consumed by space heating, water heating and refrigeration (including air conditioning and freezing). Home energy users must attempt to conserve energy regardless of use. Since, small appliances (include lighting), cooking, laundry and television account for about 15% of home energy users, particular attention to energy conservation must be paid to those uses consuming the bulk of home energy.

Energy Activity	Average % Per Residence	Average % National Total
Space Heating	57.7	11.5
Water Heating	14.9	3.0
Refrigeration	6.0	1.2
Cooking	5.0	1.0
Air Conditioning	3.7	.7
Television	3.0	.6
Food Freezing	1.9	.4
Clothes Drying	1.7	.3
Other (lighting, small appliances)	5.8	1.1

Table 5.A Annual Energy Use in the Home

Shows major home energy activities and their respective percentages of total home and national energy consumed.

Purchasers and/or users of appliances should be aware that the availability of natural gas for appliances may be a problem in some locations in the upcoming years. While many gas appliances may be more efficient than comparable electric appliances, potential non-availability and cost increases of natural gas may make it a less desirable, long-term investment when compared to electric appliances.

Purchasers and users of appliances should also be aware that, as a rule of thumb, the more conveniences and accessories an appliance has, the more energy the appliance will consume. That is, the more work the appliance must do (as opposed to being done manually by the owner/user) the greater the amount of energy required to power the appliance. For example, frostfree refrigerators/freezers, self-cleaning ovens and washer/dryer units with combinations of accommodations and numerous settings all have capabilities to perform functions (often at added energy costs/use) which might be done by hand or with other comparable machines and appliances with added "conveniences" and accessories often are more expensive to purchase initially, and thereafter to maintain and/or repair simply due the added complexity afforded by the accessories/conveniences.

It is important for the consumer to be well informed before purchasing an appliance. Common sense tells one that the more energy efficient an appliance is, the cheaper and easier it will be to operate over the life of that appliance. Care should also be taken to buy appliances that are sized to suit one's needs. An oversized refrigerator that is always half full is not a good investment. Buy to fit your needs.

To obtain optimum energy efficiency, many appliances, such as furnaces, dryers and air conditioners, have filters which must be serviced regularly. Service manuals should be consulted for information about frequency and type of filter or other maintenance.

Appliances should be located strategically to obtain optimum efficiency. For example, it would not make energy sense to place a cooking stove next to a refrigerator since the stove heat generated will make the refrigerator work harder to cool its contents. Another example of strategic appliance placement is locating a clothes dryer or water heater in a warm and well insulated area of the home as opposed to a cool area.

Before buying any household appliance, do some research by comparing the various brands regarding energy efficiency, operating costs, etc. An excellent way to compare models is through consumer oriented publications such as Consumer Reports, Consumer Research or Consumer Digest. Rate appliances, according to the publications, on quality, dependability, and cost of operation.

Space Heating

Space heating consumes nearly 60% of all energy used in the home. Thus, space heating is the single greatest consumer of energy in the home. Energy conservation techniques concentrated on this energy activity make the greatest reduction in home energy use. A thorough discussion of space heating is located in unit 4 of the PRIMER.

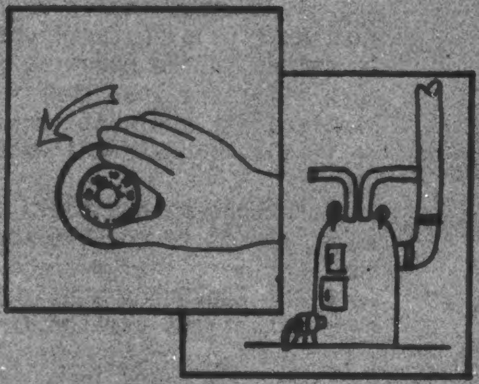
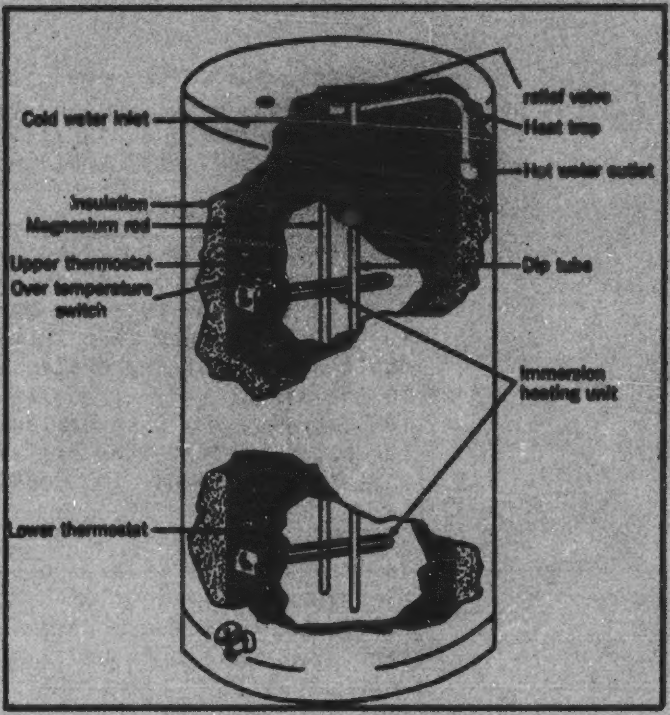


Figure 5.5 Electric water heater. Glass lined to prevent rust and corrosion; calrod immersion units to achieve desired temperature by direct contact with heat source; over-temperature switch cuts off electrical power to heater when water reaches 190°F. (Peet)


relief valve
Heat trap
Cold water inlet
Hot water outlet
Insulation
Magnesium rod
Upper thermostat
Dip tube
Over temperature switch
Immersion heating unit
Lower thermostat

HOT WATER HEATING

Water heating consumes approximately 15% of the energy used in a household. Modern water heating is generally accomplished by applying heat to an enclosed tank (usually 30 or more plus gallons). See Figures 5.5 & 5.6. The principle that warm water rises is applied in the water heater design. Cold water enters the tank at the bottom and hot water leaves the tank at the top. Water heaters which have a top and bottom heating element of one or more tubular units each are controlled by two thermostats, or a single thermostat having a double-throw action.

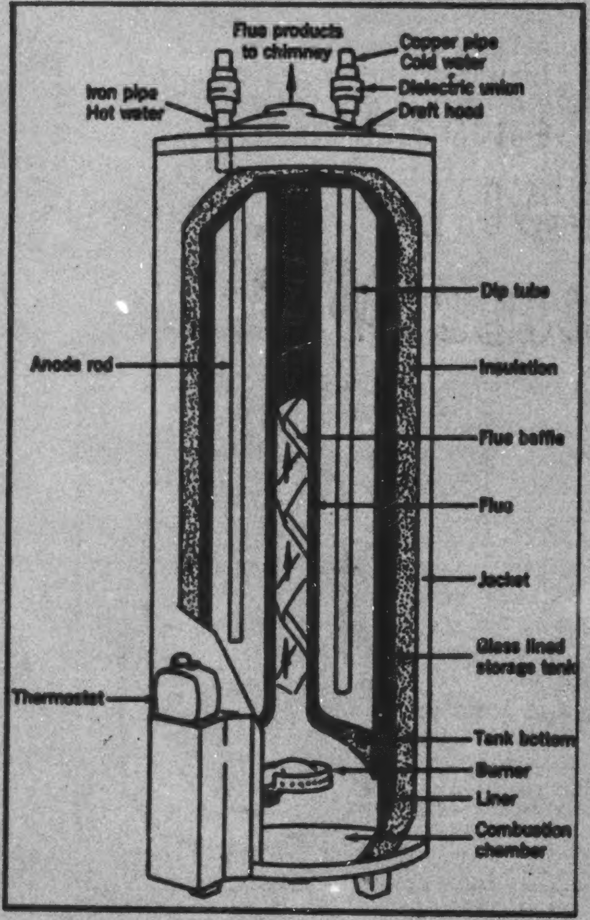

Flue products to chimney
Copper pipe Cold water
Iron pipe Hot water
Dielectric union
Draft hood
Dip tube
Anode rod
Insulation
Flue baffle
Flue
Jacket
Glass lined storage tank
Thermostat
Tank bottom
Burner
Liner
Combustion chamber

Fig. 5.6 Gas water heater-center flue. Flue products vented through tank by means of a vertical tube up the center of the tank. Spiral flue baffle inserted in flueway slows velocity of flue products causing turbulence of flue gases. This forces them to scrub or come in contact with surface of tube increasing heat transfer. (Peet)

Energy consumption for water heating is second only to space heating. Therefore, water heating use should be given a high priority in a home energy conservation plan. The following ideas will help conserve hot water and, therefore, energy.

- REDUCE "STAND-BY" HEAT LOSS.- You can easily conserve energy and save money by reducing "stand-by" heat loss from your water heater. What is "stand-by" heat loss? Imagine placing a pot of water on your range and heating the water to 140 degrees and then turning off the heat. Even if you don't use any of the heated water it will soon lose heat to the air around it. So to keep the water temperature at 140 degrees, you must periodically turn on the heat under the pot to replace the heat loss during "stand-by." The same thing happens with your water heater.

- INSULATE HOT WATER HEATER - Even though your water heater is insulated, keep in mind that insulation does not completely stop the loss of heat, but merely slows it down. However, if you add more insulation over the outside of the tank, you can reduce or slow the "stand-by" heat loss even more.

There are several water heater insulating kits available from insulation or building supply dealers. These kits are effective, but you can do just as well with a few simple materials costing about $15. AN AVERAGE ELECTRIC WATER HEATER OWNER CAN EXPECT TO RECOVER THIS COST THROUGH ENERGY SAVINGS IN ABOUT ONE YEAR.

Just follow these easy directions:

MATERIALS

1. One roll of 23-inch wide, R-19 insulation with Kraft-paper backing.
2. One roll of two-inch masking tape.
3. A standard desk stapler.
4. A pair of heavy-duty scissors.

TO APPLY

A. Open the roll of insulation Starting at the bottom of the electric water heater, place the insulation around the tank. (Figure 5.7)

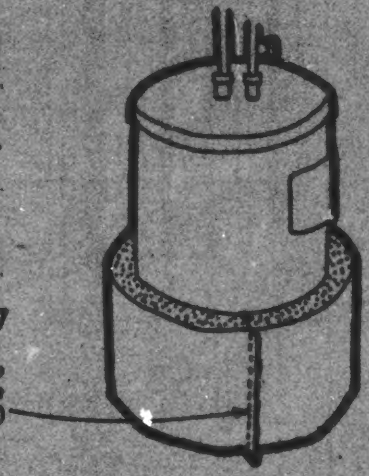


Figure 5.7

Form tab
and staple
(6 or 8 staples)

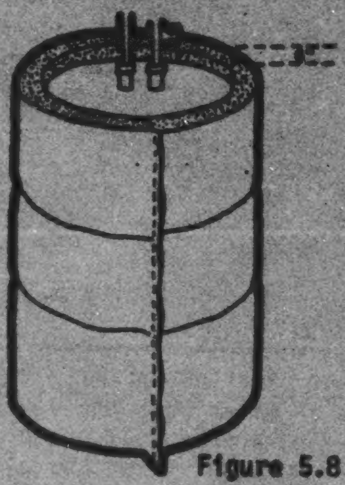


Figure 5.8

IMPORTANT: DO NOT COMPRESS THE INSULATION AROUND THE TANK. ALLOW IT TO RETAIN FULL THICKNESS.

Form a tab with the kraft-paper backing and staple the paper to hold the insulation in place.

B. Continue to wrap the electric water heater in sections until the wrap extends six inches above the top of the tank. (Figure 5.8)

Cut a piece of insulation to fit into the space at the top of the tank. (Figure 5.9)

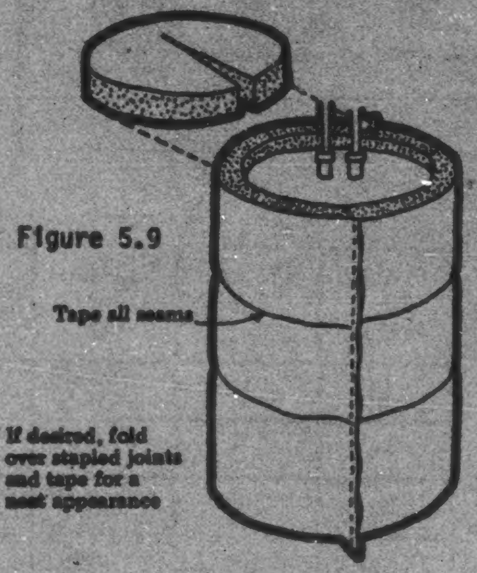
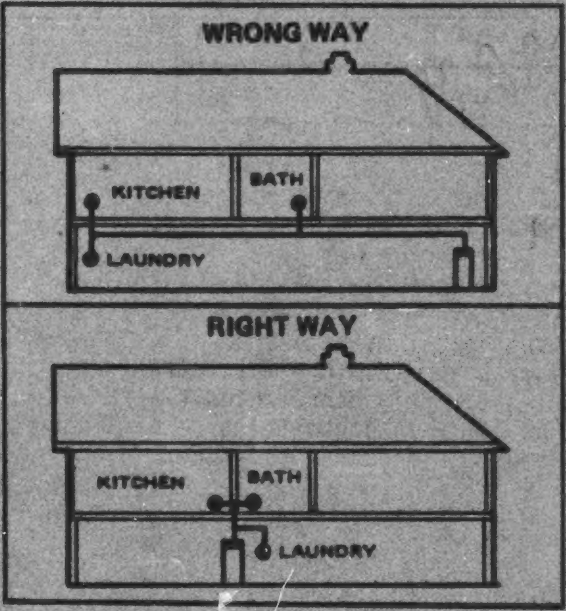

Tape all seams
If desired, fold over stapled joints and tape for a neat appearance

Figure 5.9

C. Tape all seams.

NOTE: The above procedure applies only to electric water heaters. Insulating kits can be used safely on gas water heaters when installation instructions are followed carefully. Extreme care must be exercised when installing the insulation on a gas water heater. Consult manufacture.

- ELIMINATE LONG PIPE RUNS FOR HOT WATER - Example: If 1/2" copper pipe is used in a 20 foot run, 1.9 quarts of water must be drawn off before 120°F water comes through the faucet. Suppose that at the point of greatest use (kitchen) the homeowner has a minimum of 6 draw-offs a day. The rate of 1.9 quarts times 6 draw-offs equal 11.4 quarts or 2.85 gallons that are wasted each day at just one hot water use location. This amounts of 1,040 gallons of water a year. To reduce the BTU loss from pipes we recommend:
-Locating the water heater close to the main usage center (the shorter the pipe run, the less heat loss).


WRONG WAY
KITCHEN
BATH
LAUNDRY
RIGHT WAY
KITCHEN
BATH
LAUNDRY

- INSULATING THE HOT WATER PIPES from the heater to points of use. Insulation for pipes may be found in wrap-around insulation kits, rigid foam or rubber type. Most building supply houses and plumbing outlets carry one type or another.

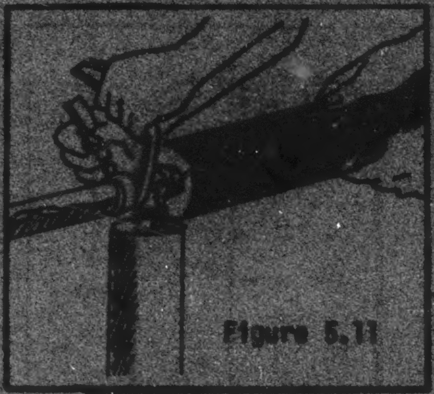
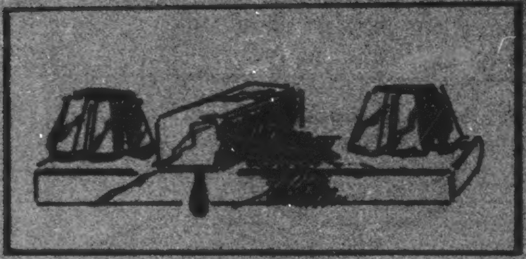


Figure 5.11



- FIX ANY DRIPPING FAUCETS QUICKLY - Drops of water cost money. The following are typical examples of how much hot water and electricity can "go down the drain" through leaky faucets.

Table 5.8 Gallons/Cost of Dripping Faucets

Drops Per Minute	Gallons Per Month	Gallons Per Year	KWH Per Month	KWH Per Year	Cost * Per Month	Cost * Per Year
30	73	876	18	216	.86¢	10.36
45	138	1656	33	396	1.58	19.00
60	192	2304	48	376	2.30	27.64
90	310	3720	78	936	3.74	44.93
120	429	5148	107	1284	5.13	61.63
* Based on 4¢/kilowatt hour						

- LOWER THERMOSTAT SETTINGS. If you never run out of hot water, the thermostat may be set higher than your needs. A standard electric water heater will use 3% less energy per every 10° water temperature set back if the surrounding air is 70°F. If the temperature of the water in the heater is reduced by lowering the thermostat setting, the heat losses to the surrounding air from the heater jacket and from the hot water piping in the house will be diminished. This constitutes to a savings in electricity. Water at 140°F is adequate to do all household chores, 120°F is adequate without a dishwasher.

- **INSTALL A LOW-WATTAGE, LARGE STORAGE WATER HEATER.** Whether you are installing a water heater in a new home or replacing an existing water heater use a low-wattage large storage water heater. A low-wattage water heater is a standard water heater equipped with heating elements of 2500 watts or less.

- **SWITCH FROM SET-DOWNS TO STAND-UPS.** Take showers instead of baths. A short shower uses much less water than a tub bath. If you must sit, use cooler water and less of it. The cost of a bath is determined mainly by the energy used to heat the water. The water itself is very cheap. The amount of energy used will depend on the amount of water and the temperature. Below is a table to illustrate the cost of a bath. The table assumes you have a standard bath. The volume is related to the depth of the water before getting in. It is also assumed the water is heated by electricity at a cost of 4 cents per kilowatt hour.

Figure 5.13

-Depth of Water	Temperatures of Water		
Inches	Warm (112°F.)	Hot (140°F.)	Very Hot (158°F.)
4"	12¢	16¢	20¢
5"	16¢	22¢	26¢
6"	20¢	26¢	30¢
7"	24¢	30¢	36¢
8"	26¢	34¢	40¢
9"	30¢	38¢	46¢
10"	34¢	52¢	50¢

Table 5.C Cost of Taking a Bath

Other Tips Concerning Hot Water

- AVOID CONTINUOUS RUNNING OF HOT WATER for washing and rinsing dishes, shaving or other purposes.
- USE COLD WATER with a garbage disposal.
- GOING AWAY FOR A FEW DAYS? TURN THE WATER HEATER DOWN OR OFF.
- USE FULL LOADS in the clothes washer or dishwasher. For maximum laundry saving, use warm or cold wash and rinse whenever possible. Also, the door of the dishwasher can be opened after washing for the drying cycle - the heat of the water will dry the dishes sufficiently.
- Once or twice a year, drain a full bucket of water out of the tank to REMOVE THE SEDIMENT BUILD-UP. The sediment insulates the tank from heat and wastes energy.

REFRIGERATION SYSTEMS

A significant amount of energy (11.6%) in the home is consumed through cooling, in refrigerators (6%), air conditioning (3.7%) and freezers (1.9%). As indicated earlier, the basic mechanical principles involved in refrigeration require a refrigerant (usually R-12) to circulate through the appliance, change from a liquid into a gas in the cooling compartment, absorbing heat which then covers the compartment temperature. The R-12 refrigerant then returns to the condenser, changing again to a liquid, and completing the cycle by recessing into the condenser heat absorbed in the cooling compartment. See Figure 5.4.

Electrical energy is required in the refrigeration mechanism to power the fan which circulates the cool air and compressor units. Some refrigerators and other cooling units are now equipped with an "Energy Saving Switch" which, according to its manufacturers, is an attempt to synchronize compressor and fan motors according to needs and climatic conditions. Systems running separately at sporadic intervals, the Energy Saving Switch provides a more coordinated operating cycle so electricity operates the equipment in unison for maximum efficiency.

Refrigerators & Freezers

The following ideas can lower the energy required for refrigerators and freezers.

- Since refrigerators and freezers don't put in cold air, but rather remove heat they should be ADEQUATELY VENTILATED. Unless the unit is designed to be built in, restricted air circulation will cause the compressor to work over time and use more energy. Refrigerators and freezers should BE AWAY FROM HEAT SOURCES such as ranges, heaters and direct sunlight. It has been estimated, for example, that a 15 cu. ft. frost free refrigerators will consume 30% less energy when the room temperature is 70°F. than when 90°F.

- A THERMOMETER MOUNTED INSIDE CAN ASSURE A PROPER TEMPERATURE SETTING; 37° to 42° in the refrigerator, and 0° in the freezer section are required temperatures for maximum efficiency. Too high temperature setting means food spoilage, too low wastes energy.

- It is important to MATCH THE REFRIGERATOR OR FREEZER TO ONES NEEDS. Over-sized units are wasteful and under-utilized. Try to keep the unit full of food but without overcrowding. A half empty appliance uses more energy, because air is harder to keep cold than chilled foods and liquids. A refrigerator or freezer operates at peak efficiency when filled to capacity but not overfilled.

- DON'T FREEZE TOO MUCH FOOD AT ONE TIME. Put no more unfrozen food into your freezer than will freeze solid within 24 hours - this is 2-3 pounds of food to each cubic foot of capacity. Overloading a freezer with unfrozen food forces the mechanism to run overtime and may overheat the motor - food will freeze too slowly to maintain the best quality.

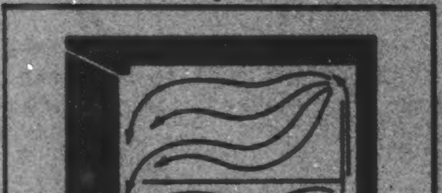


Figure 5.14 A frost-free upright freezer. 1. Cooling coil (A), hidden from view, is below and completely apart from the storage compartment. A blower (B), located behind the storage compartment, draws air through the coil where it's chilled and dried. 2. From there, it is blown up through a duct in the back wall of the storage compartment, and into the compartment through shelf-level vents (C). 3. The cold, dry air circulates throughout the cabinet-absorbing all frost-causing moisture and heat. 4. Air then passes out of storage compartment through a grille at the bottom, front (D), and returns to the cooling coil, where the process begins again. Once every 24 hours, the blower stops and electric heaters melt the frost from the hidden cooling coil. The heat of the compressor evaporates melt-water into the air outside the freezer. (Peet)

- AVOID OVERCROWDED SHELVES which blocks air circulation.

- Before opening the door KNOW WHAT YOU ARE LOOKING FOR. Frequent and prolonged door opening lets in warm air. Appliances work harder, use more power. Be extra careful in hot weather.

- FROST IS AN INSULATOR--never allow more than 1/4" to build up on a surface.

- KEEP COILS AND FINS CLEAN. Condenser coils in refrigerator need freezers, like in air conditioners, tend to collect dust and dirt (especially in carpeted kitchen). When they are dirty, they use more energy, so your appliance coils should be cleaned once a year!

- Make sure that door GASKETS SEAL PROPERLY--close the door on a dollar bill, if it falls out or slides out easily when pulled, the gasket has a poor seal and is wasting energy - replace if this is the case.

- GOING AWAY FOR A VACATION? DECREASE ENERGY USE BY RAISING THE TEMPERATURE in the refrigerator-it will remain cold enough since the door will not be opened while you are away.

- ALLOW FOODS TO COOL before putting them in the refrigerator.

- Manual defrosting models require more work to defrost as opposed to frost-free models. However, since most frost-free models defrost through the use of a heating coil to melt the frost, additional electrical energy is required. (See Figure 5.14)

Air Conditioning

Air conditioning (AC) systems are usually one of two types: (1) central AC designed to cool the entire house by using the forced air ductwork, and (2) window AC intended to cool only one or two rooms. Here are some helpful hints about AC:

- For the best and most efficient results, INSTALL AC IN THE MIDDLE OF THE AREA TO BE COOLED. Avoid hallway and corner placement if possible. Also, place AC on the shady side of the house so heat can escape from the condensing coils easier.

- DON'T EXPECT ONE WINDOW AC UNIT TO COOL YOUR ENTIRE HOME. Normally, you'll need several units to provide cooling equal to a central system. Also, the operating cost will run from 15% to 20% higher than with central AC. Single room sized window units used only when needed can be more efficient than a central AC unit.

- If your home has a central, warm air furnace, close the floor or wall registers and low return air grills while using your window AC. This keeps cool air from escaping out of your living area.

- By leaving your AC on at night at a higher thermostat setting, you will eliminate the need to completely re-cool your home the next day. Depending on weather, it may be more economical to leave the AC on rather than to restore cool air each day.

- Using the PROPER SIZED AC is very important since one of its primary functions is to remove moisture from the room. An oversized unit will not accomplish this and will be more expensive to operate.

- During hot months, DO HOUSEHOLD CHORES WHICH REQUIRE HOT WATER OR PRODUCE HEAT DURING THE COOLEST TIMES OF THE DAY--early morning, late evening.

- KEEP STORM WINDOWS AND DOORS IN PLACE AND TIGHTLY WEATHER-STRIPPED to reduce AC load.

There are also natural ways to effectively cool a house which require no energy. Here are a few suggestions:

- BLINDS AND DRAPERIES REDUCE HEAT GAIN through windows by as much as 50 percent. Light-colored, opaque DRAPES REFLECT SUN AND KEEP HEAT OUT best. Keep drawn during the day and open during cooler hours of the evening.

- AWNINGS, OVERHANGS, AND TREES to shade windows are the most effective way to REDUCE SOLAR HEAT GAIN. They cut heat gain as much as 80 percent.

- PAINT the outside of your HOME A LIGHT COLOR AND HAVE A LIGHT-COLORED ROOF. A dark-colored surface exposed to direct sunlight can get as much as 60 degrees hotter than the air temperature. A white surface will only heat up to 20 degrees more than the air temperature.

- A breeze can be maintained within the home by using the "chimney effect" of ventilation. This operates on the concept that warm air expands and gets lighter, thus heavier, cool air displaces it. To use this principle, provide openings in the lower level of your home for cool air to enter and at upper levels for warmer air, which rises, to escape. The upper openings should be larger than the lower openings since the air picks up heat within the home and expands. The "chimney effect" will provide a CONTINUOUS AIR MOVEMENT inside, even when there are no breezes outside.

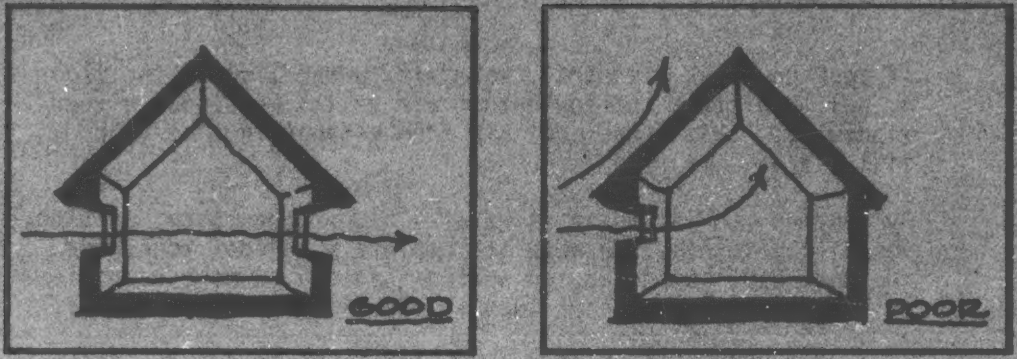


Figure 5.15 (Adam)

- ATTIC VENTILATION is especially important. Unventilated attic temperatures can reach 175° Fahrenheit. This heat seeps down into the home--and can increase the AC load of your "Average" home by as much as 12,000 BTU's per hour. (This value would hold for a home with essentially no insulation in the ceiling).

Dishwashers

Dishwashers can use less hot water than washing dishes by hand, depending on personal dishwashing habits and other factors. The basic mechanics principle involved in an automatic dishwasher is a circulating spray of pressurized, hot, detergent water in various cycles. Energy is used in dishwashers to power pumps, controls, numerous circulating devices, to heat the water and to dry the dishes. Here are some ways to cut energy use with automatic dishwashers:

- DISHWASHERS RUN MOST ECONOMICAL AT FULL CAPACITY-accumulating dishes from several meals is the best thing to do. Dishes can be rinsed with cold water and scraped before placing in the unit to prevent difficult washing.

- AVOID THE DRYING CYCLE. The power saver switch (on some models) can be used to shorten or eliminate drying cycles and save energy. Use the power saver switch or advance the control to off after washing is completed. Immediately open the door. The hot dishes will air dry quickly while the moisture will make the house more comfortable in winter. 1/3 to 2/3 of the total electricity used by a dishwasher can be saved by no heat drying.

- Never use detergent that isn't specifically designed for dishwashers. Detergents made to work at 140° plus will not clean effectively at lower temperatures.

- Make sure hot water is at 140° for maximum efficiency.

Stoves

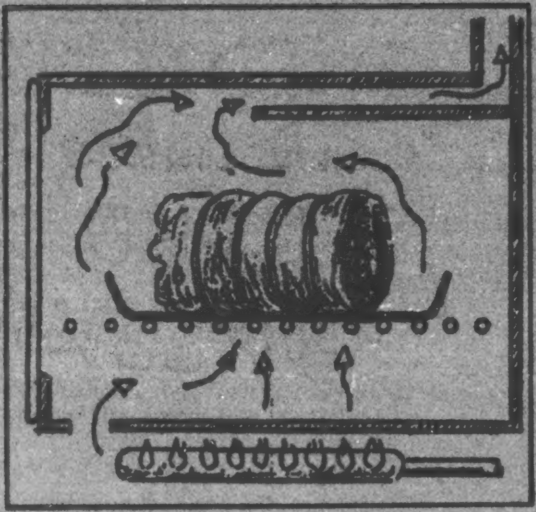


Figure 5.16 (Koff)

Cooking consumes approximately 5% of all energy used in the home. Ranges and ovens are responsible for approximately 4% while the rest is made up through small appliances.

The basic principle involved in cooking is that heat (usually provided by electricity or gas) acts upon and is absorbed by a colder food item (see Figure 5.16).

No judgement is made here of the relative efficiency of gas and electric stoves. Although a gas appliance uses more energy than an electrical one in a similar operation, the added energy used to generate electricity makes gas more efficient. The average American electric generation and transmission system must use 3.67 BTU's of energy for every 1 BTU delivered to the appliance. Gas uses only 1.4 BTU's of energy for every 1 BTU delivered. Price controls and local availability will determine the actual operating costs: however, from an energy conservation viewpoint, gas should be used instead of electricity.

The following ideas can help reduce energy consumption on cooking:

- Pilot lights on gas stoves consume 20-50% of the total gas used. Newer models with AUTOMATIC IGNITION AND NO PILOT LIGHT SAVE VALUABLE GAS.
- GAS FLAMES SHOULD BE BLUE - if they are yellow the burner is probably dirty, should be checked and cleaned. Also, there SHOULD NOT BE A GAP BETWEEN THE BURNER AND THE FLAME. If the pressure is too high, it should be adjusted by a professional.
- CHECK THE OVEN SETTING WITH A THERMOMETER to insure accuracy.
- When using the oven, PLAN SEVERAL ITEMS AT ONCE. DON'T OPEN THE OVEN DOOR OR LIFT THE LIDS ON POTS UNNECESSARILY. This lets out heat and wastes energy and slows the cooking time. (Remember: A watched pot never boils!!)
- USE A PRESSURE COOKER WHEN POSSIBLE. It lessens cooking time and fuel use.

- USE PANS THAT ARE APPROPRIATE FOR THE BURNER SIZE. Also, USE THE PROPER FLAME for the proper job.

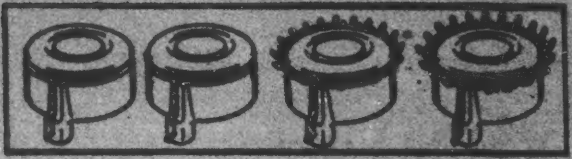


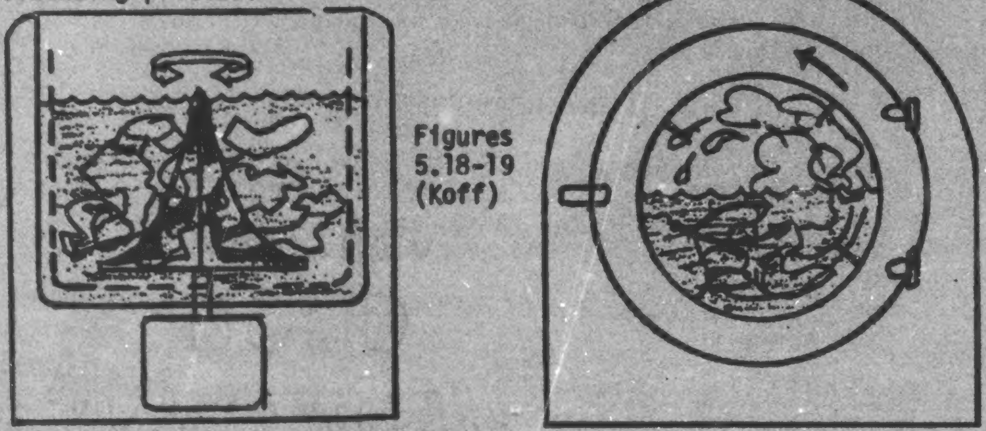
Figure 5.17 Gas burners make available the exact heat needed, from the tiny "keep warm" flame to "gentle simmer," "medium high," and "high." (Peat)

Giant - not less than 12,000 BTU per hour.
Regular - not less than 9,000 BTU per hour.
Simmer - not less than 1,200 BTU per hour.
Pilot - not more than 300 BTU per hour.
Minipilot - not more than 125 BTU per hour.

- SELF-CLEANING and CONTINUOUS-CLEANING ranges are better insulated and more efficient uses of energy.
- TURN OFF THE HEAT A FEW MINUTES EARLY - residual heat will continue to cook the food.
- Use TOASTERS, TOASTER OVENS, and ELECTRIC SKILLETS for small jobs as they require less energy than major appliances.
- NEVER USE AN ELECTRIC STOVE FOR A HEATER OR HAIR DRYER. It is inefficient, and the stove can be damaged by heating for prolonged periods.
- THAW FOOD BEFORE COOKING.

Laundry Appliances

Laundering clothing consumes about 2% of all energy used in the home. The principles involved in washers are usually of two types: 1) clothes are tumbled clean by a rotating drum half-filled with soap and water; or, 2) clothes are agitated clean by an up and down, back and forth movement. In both cases, motors, timers, pulleys, switches and other mechanical hardware are involved in the cleansing process.



Figures 5.18-19 (Koff)

Dryers use a rotating drum to tumble the clothes in warm air. The warm air is supplied by electricity or gas and is moved through the drum by means of a fan. A filtering device is a critical component in all dryers, catching loose lint and debris. Again timers, pulleys, switches, motors and other mechanical hardware are integral parts of the dryer system. These require electrical energy to function. However, the major energy consumption involved in laundering is the electrical or gas heat required to dry clothes after washing and to heat the wash water.

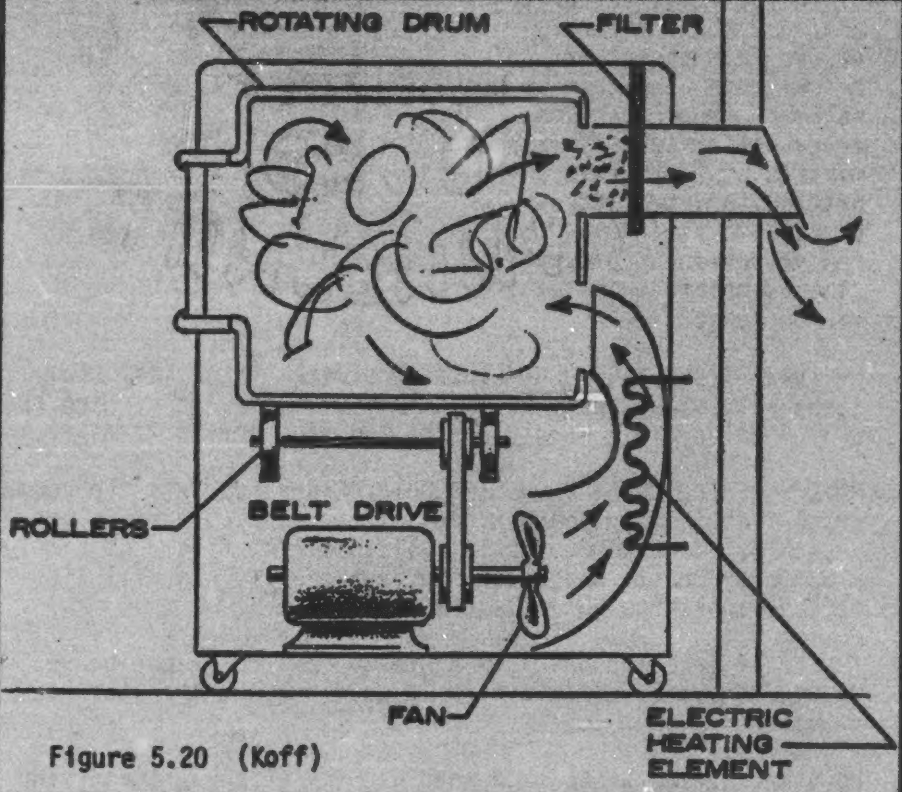


Figure 5.20 (Koff)

The following tips should help conserve energy when laundering.

- Most of the energy used for washing clothes is used to heat the water. REDUCE THE ENERGY REQUIREMENT BY USING WARM OR COLD WASH, always use cold rinse.

- USE FULL LOADS BUT DON'T OVERLOAD. Plan the washday schedule. Don't use the washer or dryer more than you have to. Wait until you have a full load.

Figure 5.21

- Be sure to KEEP THE DRYER FILTER CLEAN to reduce energy requirements by shortening the drying time. This increases drying efficiency. Also, CHECK AND CLEAN THE DRYER EXHAUST on the outside of the house occasionally. If it's partially clogged, it can lengthen drying time and increase energy consumption.

- OVERDRYING WASTES ENERGY and also sets wrinkles in clothes. It is better to underdry than overdry. Remove from the dryer quickly and hang them up--it saves ironing. Some dryers offer several extra minutes of fluff (without heat) with intermittent signals to remind you to remove permanent press clothes before wrinkles can be re-set.

Figure 5.22

- DRY LIKE ITEMS TOGETHER--synthetics with synthetics, heavy items with other heavy items. This will prevent running an additional cycle for only one or two slow drying items.

- MAKE SURE THE DRYER IS VENTED OUTSIDE and not into the room. Dryer lint is very combustible. If an outside vent is not possible, use a commercially available lint filter or simply place a nylon stocking over the vent pipe. This will allow the air to escape but will trap any lint.

- Try to INSTALL THE DRYER IN A HEATED PORTION of the house. It won't have to work as hard in cold weather and will conserve energy.

- By using a HIGH-SPEED SPIN when washing clothes, the drying time is shortened. This can contribute substantial energy savings.

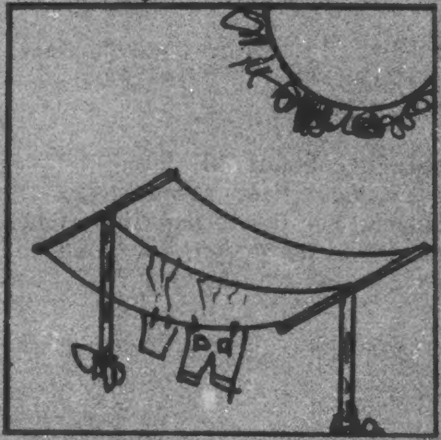


Figure 5.23

- To conserve energy USE A CLOTHES LINE OR "SOLAR" CLOTHES DRYER whenever possible.

- Washers with adjustable water level controls are capable of significant energy conservation. SELECT THE WATER LEVEL TO MATCH THE SIZE OF THE LOAD. Soaking heavily soiled garment in a detergent or soak solution before washing will allow shorter wash times. Washing longer than necessary wastes energy.

Table 5.0

ESTIMATED YEARLY KILOWATT-HOUR USE AND APPROXIMATE OPERATING COSTS FOR VARIOUS HOUSEHOLD APPLIANCES

APPLIANCE	AVERAGE WATTAGE	KWH PER YEAR	EXAMPLE COST PER KWH @ .0398 (for accurate cost use your present electric rate)
Air Conditioner	860	860	34.23
Blanket, Electric	177	147	5.85
Blender	386	15	.60
Broiler	1,436	100	3.98
Carving Knife	92	8	.32
Clock	2	17	.68
Clothes Dryer	4,856	933	37.13
Coffee Maker	894	106	4.22
Deep Fryer	1,448	83	3.30
Dehumidifier	257	377	15.00
Dishwasher	1,201	363	14.45
Fan, Attic	370	291	11.58
Fan, Window	200	170	6.77
Freezer, 15 cf	341	1,195	47.56
Freezer, Frostless 15 cf	440	1,761	70.09
Frying Pan	1,196	186	7.40
Hair Dryer	381	14	.56
Heater, Portable	1,322	176	7.00
Heating Pad	65	10	.40
Humidifier	177	163	6.49
Iron, Hand	1,008	144	5.73
Mixer	127	13	.52
Microwave Oven	1,450	190	7.56
Range with Oven	12,200	1,175	46.77
Range with Self-Cleaning Oven	12,200	1,205	47.96
Radio	71	86	3.42
Refrigerator, 12 cf	241	728	28.97
Refrigerator Frostless, 12 cf	321	1,217	48.44
Refrigerator/Freezer 14 cf	326	1,137	45.25
Refrigerator/Freezer Frostless, 16 cf	615	1,829	72.79
Sewing Machine	75	11	.44
Shaver	14	1.8	.07
Toaster	1,146	39	1.55
Trash Compactor	400	50	1.99
Television, Black & White, Tube Type	160	350	13.93
Television, Black & White, Solid State	55	120	4.78
Television, Color Tube Type	300	660	26.27
Television, Color Solid State	200	440	17.51
Vacuum Cleaner	630	46	1.83
Washing Machine, Automatic	512	103	4.10
Washing Machine, Non-Automatic	286	76	3.02
Waste Disposer	445	30	1.19
Water Heater	2,475	4,219	167.92
Water Heater Quick Recovery	4,474	4,811	239.59
Electric Furnace		13,200	525.36
Heat Pump		6,600	262.68

Small Appliances

Over the years, the number of small appliances in a normal household has grown dramatically. We used to think of such items in terms of electric toasters, irons, mixers, and bacuum cleaners. Today, we're talking in terms of everything from electric toothbrushes and hot combs to color television and stereo. Stop for just a moment and figure how many small electrical appliances are used in the home. The important thing to remember is that they all use energy. (See Table 5.D). Proper use and wise management of these items can make a difference. Sometimes they make contributions to energy conservation. Often they fall into a wasteful category of electrical gadgets.

The best energy tip for all small appliances is: IF YOU DON'T NEED IT - DON'T BUY IT!! Secondly, IF YOU DO USE IT - DON'T LEAVE IT RUNNING UNNECESSARILY!!

To determine total energy use of appliances and how to use the electric meter to help manage electrical use, refer to the "Utility Rates and Meter Reading" section at the end of this unit.

GOVERNMENT APPLIANCE LEGISLATION

Federal Government Legislation is pending which will ensure that manufacturers provide appliance energy information beginning Fall 1979. The legislation is intended to require many appliance manufacturers to perform tests and experiments to determine energy consumption levels and efficiencies of their products. Following this determination, the information must be clearly listed (tagged or attached) on the product at the time of sale. Typical information to be included could include appliance:

- capacity;
- estimated annual energy consumption;
- cost per kilowatt hour (if applicable);
- estimated annual cost to operate; and
- cost comparison data (to all available models and similar types).

Information (both format and content) included in the legislation is shown in the following page. Purchasers and users of appliances should become familiar with the legislation prior to acquiring new appliances.

HOW MUCH DOES IT COST TO RUN APPLIANCES ? ?

Everybody is energy-conscious. But so far there hasn't been a simple way for consumers to figure their household energy costs. Now, under a new law, the Federal Trade Commission staff is proposing that 13 categories of appliances be sold with labels giving consumers the estimated annual energy cost for an item–before they buy. Equally important, the labels would also give the range of estimated costs for comparable items.

If the FTC adopts the staff's recommendations, the next refrigerator you buy could carry a yellow and black label that looks like this example. It would give you:

Appliances to be sold with Energy Labels

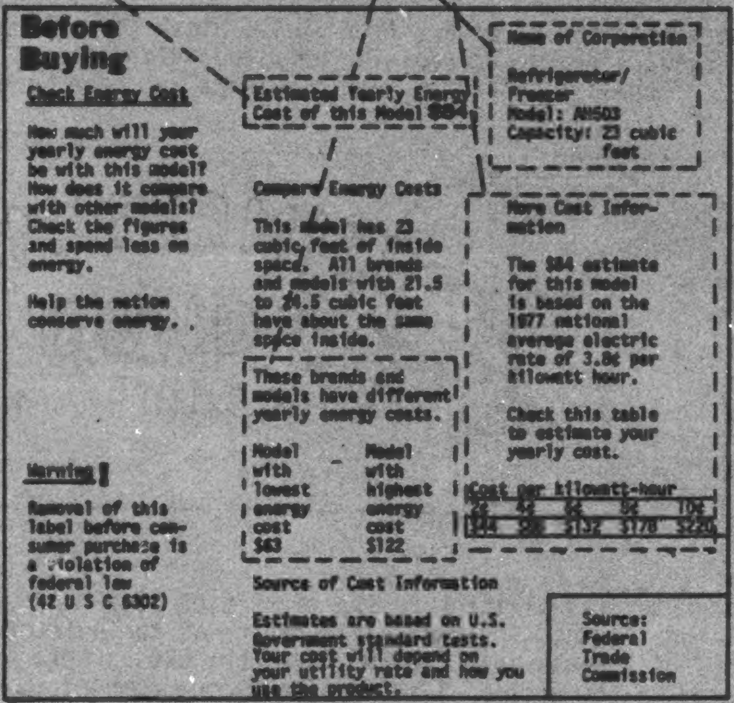
Refrigerators and refrigerator-
  freezers
Freezers
Dishwashers
Clothes dryers
Water heaters
Room air conditioners
Home heating equipment
  (other than furnaces)
Television sets
Kitchen ranges and ovens
Clothes washer
Humidifiers and dehumidifiers
Central air conditioners
Furnaces

1 A description of the model

2 The estimated energy cost of the model.

3 The range of energy costs for comparable models.

4 Other useful information that will enable you to estimate costs even more precisely.



Before Buying

Check Energy Cost

How much will your yearly energy cost be with this model? How does it compare with other models? Check the figures and spend less on energy.

Help the nation conserve energy.

Warning!

Removal of this label before consumer purchase is a violation of federal law (42 U S C 6302)

Estimated Yearly Energy Cost of this Model $84

Compare Energy Costs

This model has 23 cubic feet of inside space. All brands and models with 21.5 to 24.5 cubic feet have about the same space inside.

These brands and models have different yearly energy costs.

Model with lowest energy cost	Model with highest energy cost
$63	$122

Name of Corporation

Refrigerator/
Freezer
Model: AN503
Capacity: 23 cubic
  feet

More Cost Information

The $84 estimate for this model is based on the 1977 national average electric rate of 3.8¢ per kilowatt hour.

Check this table to estimate your yearly cost.

Cost per kilowatt-hour

2¢	4¢	6¢	8¢	10¢
$44	$88	$132	$176	$220

Source of Cost Information

Estimates are based on U.S. Government standard tests. Your cost will depend on your utility rate and how you use the product.

Source:
Federal
Trade
Commission

UTILITY RATES and METER READING

Electric Meters

Reading your own meters is an easy way to keep tabs on the amount of energy you use. From the time the meter was installed, it has measured the amount of electricity used in the house. The dials, which are called the meter register record how much the household has used. In a way, the meter register is like an automobile's odometer which records the number of miles the car has traveled. In the same way, the electric meter records the number of kilowatt-hours of electricity used. One kilowatt-hour, is the amount of electricity used by any electrical device, such as a toaster, heat lamp or vacuum cleaner, rated at 1000 watts (one kilowatt) if operated for one hour.

How much of your bill is for electricity, and how much does each kilowatt-hour cost? You cannot answer these questions without asking your utility company for a copy of the rate schedule that was applied to your bill. Be sure that you have the right schedule; rates sometimes vary according to the season. In most areas the demand for electricity increases in warm months; and to meet the added burden, electric companies are forced to use spare generators which are often less efficient and consequently more expensive to run or must purchase additional power from other utility systems.

Some electric meters have five dials, other have four. Figure 5.24 illustrates the meter register of a four-dial meter. Notice that some of the dial pointers turn clockwise and some counter clockwise.

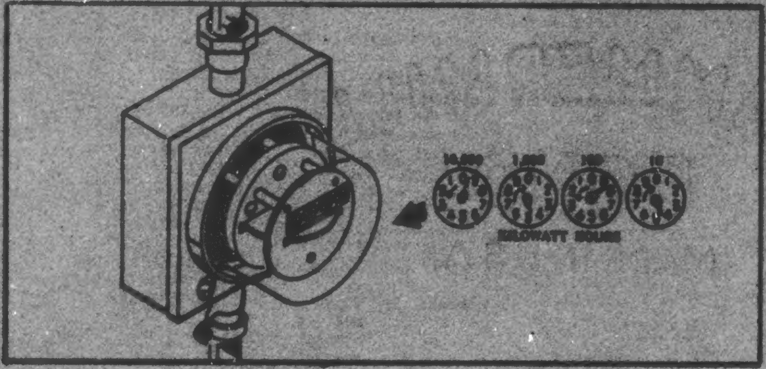


Figure 5.24

Each numerical division on the right-hand dial represents 10 kilowatt-hour (KWH). One complete rotation of the pointer on the right hand dial means that 100 KWH have been used. This will cause the pointer on the next dial to advance by one number, thus registering the use of 100 KWH. When the pointer on the second dial advances by one number it registers the use of 1000 KWH - and so on, for the rest of the dials. The pointers on the electric meter are geared to each other and to the disc below them. The greater the electric usage at one time, the faster the disc spins. How to interpret your electric meter:

1. Read dials from left to right. (Note that numbers run clockwise on some dials and counterclockwise on others).

2. If a pointer is between two numbers, read the lower number unless the pointer is between nine and zero. (The zero stands for ten). For example, in the diagram the pointer on the first dial is between 0 and 9--read 9. The pointer on the second dial is between 5 and 4, read 4. Read 8 on the third dial and 4 on the fourth. Thus, the total reading is 9,484.

3. This reading is based on a cumulative total--that is, since the meter was last set at zero, 9,484 kilowatt-hours of electricity have been consumed. (To find your monthly consumption, take two readings one month apart, and substract the earlier one from the later one.

4. The figures above each dial designate how many kilowatt-hours are recorded each time the pointer makes a complete revolution.

How to determine your kilowatt use:

If you want to know how many miles you drove last month, you subtract the odometer reading you took last month from todays reading. That's also the way you determine how many kilowatt-hours of electricity you used in the last month. You simply subtract the meter reading you took a month ago from todays reading.

How to use your meter to help you manage your use of electricity:

Read your electric meter at about the same time every day. Using the form below write in the date next to the day of the week and record your reading under the column "Meter Reading". Subtract yesterday's reading from todays and record the difference under "Kilowatt-hours Used". This is the amount of electricity used during the last 24 hours. Compare todays kilowatt-hour usage with yesterday's usage or with usage for the same day of last week.

After a few weeks, "Watt Watching" will help to identify activities which use the most electricity. From this record keeping system, elimination or curtailment of wasteful energy should be decided.

Month_______________

Date	Day of Week	Meter Reading	Kilowatt Hours Used	Reason for Increase or Decrease

WEEKLY TOTAL__________

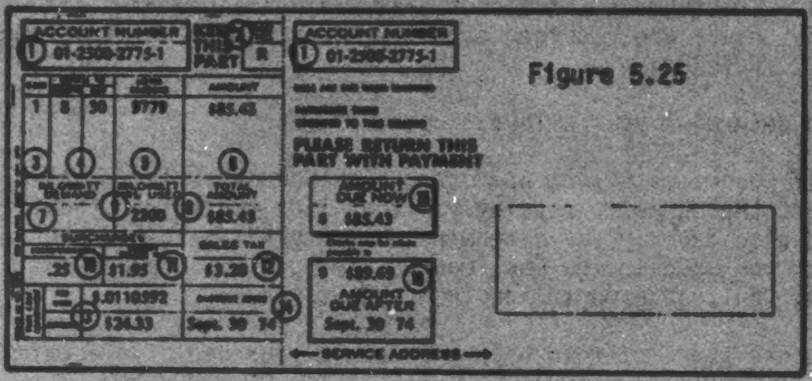

ACCOUNT NUMBER
① 01-2500-2775-1
KEEP THIS PART R
1 8 30 9779 $85.43
③ ④ ⑤ ⑥
⑦ ⑧ 2300 ⑨ TOTAL AMOUNT $85.43
SURCHARGES
SALES TAX
.25 ⑩ $1.95 ⑪ $3.20 ⑫
$.0110392
$24.33
Sept. 30 74
ACCOUNT NUMBER
① 01-2500-2775-1
PLEASE RETURN THIS PART WITH PAYMENT
AMOUNT DUE NOW
$ $85.43
$ $89.69
AMOUNT DUE AFTER Sept. 30 74
SERVICE ADDRESS

Figure 5.25

Electric Billing

The numbers in the following list identify the parts of the sample bill.

1. Your customer account number.
2. A code showing which of the rate schedules was applied to your bill. A typical rate schedule is shown below.
3. A code showing whether your bill was estimated or adjusted.
4. Date on which the billing period ended.

5. Number of kilowatt-hours your meter registered when the bill was tabulated.
6. Itemized list of charges. In this case, the only charge shown is a figure determined by adding the price of the electricity you have consumed to the routine taxes and surcharges. Had you, however, received some special service during this billing period, a service charge would appear in this space as a separate entry.
7. Information appears in this box only when the bill is sent to a business using more than 6,000 kWh's a month.
8. The number of kilowatt-hours you used during the billing period derived by subtracting the previous meter reading from the current.
9. Total dollar amount that you owe.
10. Environmental surcharge.
11. County energy tax.
12. State sales tax.
13. Fuel cost adjustment. Both the total adjustment and the adjustment per kilowatt-hour are shown for additional, frequently more costly back-up fuel.
14. Date on which bill, if unpaid, becomes overdue.
15. Amount due now.
16. Amount that you must pay with added surcharge if the bill becomes overdue.

The sample electric bill is based on the schedule shown below. Note that there is a minimum charge regardless of how little electricity you use, and that the first 20 kilowatt-hours you use are covered by this flat rate. (Not all rate schedules include minimum charges).

Minimum charge (including the first 20 kWh or fraction thereof)	$2.25 per month
Next 80 kWh	.0355 per kWh
Next 100 kWh	.0321 per kWh
Next 200 kWh	.0296 per kWh
Next 400 kWh	.0265 per kWh
Consumption in excess of 800 kWh	.0220 per kWh

The sample bill shows a consumption of 2,200 kilowatt-hours. To understand how to apply the rate schedule to the bill, study the following chart.

30 kWh	@	$.225 (flat rate)	=	$ 2.25
80 kWh	x	.0355	=	2.84
100 kWh	x	.0321	=	3.21
200 kWh	x	.0296	=	5.92
400 kWh	x	.0265	=	10.60
+1,400 kWh	x	.0220	=	+30.80
2,200 kWh				$55.62

The 2,200 kilowatt-hours cost $55.62. The other $29.81 ($85.43 less $55.62) is charged for the fuel cost adjustment and the various taxes and surcharges listed on the face of the bill.

Gas Meter Reading

A gas meter tallies the number of cubic feet of natural gas that you have used. Read it as you would an electric meter.

From left to right, the dials register 3,177. This is not the final reading however. It must be multiplied by 100 because each time the pointer on the right-hand dial moves from one number to another, the use of 100 cubic feet of natural gas has been recorded. Thus, the total reading is 317,700 (3,177 x 100). Since the meter was last set at zero, it has recorded the consumption of 317,700 cubic feet of natural gas.

Some gas meters have more than four dials. If yours does, and you cannot decide by what number to multiply the reading, call your gas company for directions.

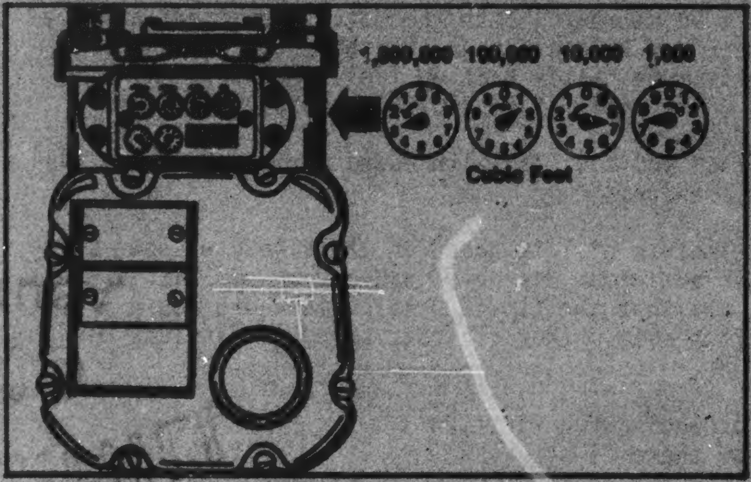


Figure 5.26

The figures above each dial show how many cubic feet of natural gas are recorded each time the pointer makes a complete revolution.

(Note that many rental housing units are not equipped with meters. Instead, the landlord has a large master meter or meters that register the amount of gas and electricity used by all of the tenants. The landlord pays the utility bills and recovers the cost through the rent charged).

Gas Billing

The numbers in the following list identify the parts of the sample bill.

1. Customer account number.
2. Sales tax

3. Date on which the bill, if unpaid, becomes overdue.
4. Code indication of charges included in this bill. The key to the code is on the back of the bill. In this case you are being charged only for gas, routine taxes, and surcharges. Had you received special services, other code indications would appear in this space.
5. A code indication of the rate schedule applied to your bill.
6. Shows how many days of service are covered by this bill.
7. Date on which billing period ended.
8. Number of cubic feet of natural gas your meter registered when this bill was tabulated.
9. Itemized list of charges. In this case, the only charge shown is a figure determined by adding the price of the gas you have used to the routine taxes and surcharges. Had you received any special services from the gas company, service charges would appear here as a separate entry.
10. The amount of gas--expressed in hundreds of cubic feet-that you used during this billing period.
11. The number of therms contained in every hundred cubic feet of gas you received.
12. The number of therms you used during this billing period.
13. The total amount owed by you if your bill is paid on time.
14. Amount you must pay including surcharges if the bill becomes overdue.
15. A temporary surcharge granted to the company by the utility commission until the commission has had time to decide whether or not to raise the company's rates.
16. Purchased gas adjustment (PGA) charge. The total PGA and the PHA per therm are both shown.

As is the case with your electric bill, you must get a copy of the relevant rate schedule from your natural gas company if you want to know either how much of your bill is owed because of the gas you used or how much each therm costs.

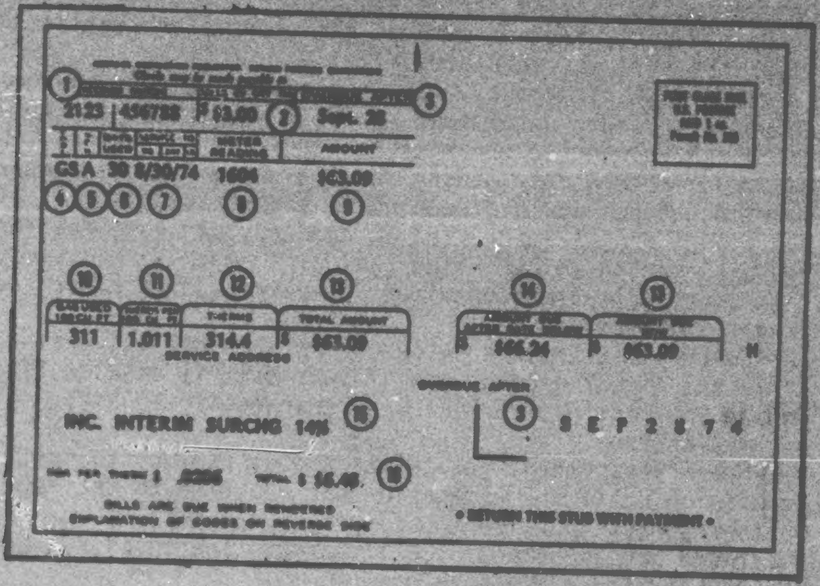
Shown below is the schedule from which the sample natural gas bill is derived. Note that, like the electric schedule, this one also contains a minimum charge.

Minimum charge (including the first 5 therms or fraction thereof)	$2.50 per month
Next 10 therms	.1690 per therm
Next 15 therms	.1560 per therm
Next 570 therms	.1424 per therm
Next 5,400 therms	.1226 per therm

The sample bill shows a consumption of 314.4 therms. To understand how to figure the cost of each therm, study the following chart.

5 therms	@	$2.50 (flat rate)	=	$ 2.50
10 therms	x	.1690	=	1.69
15 therms	x	.1560		2.34
+284.4 therms		.1424		+40.50
314.4 therms				$47.03

The 314.4 therms cost $47.03. The other $16.06 ($63.09 less $47.03) is for the purchased gas adjustment and the various taxes and surcharges listed on the face of the bill.


① 2123 | 456788 | $ $3.00 ② | Sept. 28 ③

METER READING | AMOUNT

GSA 30 8/30/74 1604 $63.09

④ ⑤ ⑥ ⑦ ⑧ ⑨

⑩ ⑪ ⑫ ⑬ ⑭ ⑮

311 | 1.011 | THERMS 314.4 | TOTAL AMOUNT $ $63.09 | $ $66.24 | $ $63.09 H

SERVICE ADDRESS

OVERDUE AFTER ③ S E P 2 8 7 4

INC. INTERIM SURCHG 14% ⑮

$ .0206 TOTAL $ $6.48 ⑯

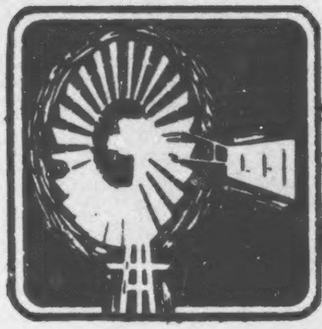
BILLS ARE DUE WHEN RENDERED

EXPLANATION OF CODES ON REVERSE SIDE

• RETURN THIS STUB WITH PAYMENT •

Figure 5.27

unit 6



ENERGY EFFICIENT DESIGN

by: M.P. Vogel

In this country approximately 22% of our total energy supply goes into our homes. Of that amount about 28% is used for comfort heating, 22% for comfort cooling, 23% for heating hot water, and the remainder for operating lighting and household appliances. Up to 40% or 50% of this energy is wasted and might be saved by more sensible ways of designing, building and living in our homes. The purpose of this unit is to illustrate the kinds of steps which can be taken to achieve such savings in this climate.

Home Energy Conservation Primer

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unit 6

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[E.E.D.] ENERGY EFFICIENT DESIGN

INTRODUCTION

Energy efficient housing is that which is designed to provide comfortable shelter with a minimum of required energy. There are many varying degrees of energy efficiency depending upon what seale one uses and with what the comparison is made. By adding storm windows or insulation most houses will be more energy efficient, but the concept is much broader than that. The energy efficient house must be viewed as a system made up of a number of interrelated parts, each of which must be made an energy efficient as possible. The parts of the housing system include site orientation, house design, construction and insulation, the heating/cooling system, and color and lighting.

What is EED?

Within the past few years, energy efficient building has become fashionable as one way to help solve the energy dilemma that has engulfed us. Energy efficient building is often thought of as a rather complex and expensive design of engineering and architecture genius with technical high technological systems. These systems are useful and give greater efficiency in our ability to stay warmer in the winter and cooler in the summer at a low cost. However, the buildings themselves are not to different from conventional ones that have been built these few decades. What is different is that they are built in response to the specific environmental demands such as available sunlight, wind, plants and tree forms, and building materials. In former times, building design was closely related to the surrounding environment. Energy and building materials were derived from the immediate area. Having only relatively primative heating and cooling technologies every effort was made to maximize positive environmental factors and minimize negative ones (e.g.: locating shelters so that they would be protected from the cold winter winds, but exposed to the light and heat from the low winter sun. Deciduous trees were planted on the south side of houses for summer shade and conifers on the north side for wind breaks).

Over the centuries, shelters have been built to reduce the range of local climate variations: to avoid some of the heat of the sun in a hot climate, to hold more heat in a cold climate to take advantage of winds where they contribute to desired cooling, to deflect or avoid winds where they exaggerate an already cold environment, to provide protection from drenching rains or chilling snows, to permit light to enter in sufficient amounts for the performance of work within the shelter and to keep out light that is unnecessary or excessive. All of these functions have been combined into characteristic form that could be built of available materials with the degree of technical complexity characteristic of the indigenous culture. Examples may be old or contemporary. They have in common a responsiveness to the complex peculiarities of their location and the development of nonmechanical ways to modify or ameliorate the conditions. Our building history is a history of energy efficient environmentally appropriate shelters.

In more recent time, (the past 75-100 years) we have moved far from these practices, utilizing new technologies and cheap abundant energy. Little or no care is taken to ensure the windows are facing toward the sun (south). The modern picture window might face in any direction, including north. Only by accident are windows placed correctly. Windows are seldom shaded, windbreaks are rarely planted. Houses are poorly insulated. We now overcome the extremes of heat and cold with air conditioners in summer and massive heating systems in the winter. Energy and building materials come from far off places. The consequences of all this are that conventional modern homes are high consumers of energy, water and other resources, high producers of waste products, and have very heavy impacts on local and distant environments.

The Energy Concern

Energy is an integral part of housing and also of great concern. The American Institute of Architects has estimated that:

> If the United States adopted a high-priority national program emphasizing energy efficient building, we could by 1990 be saving the equivalent of more than 12.5 million barrels of petroleum per day. We are now investing vast quantities of increasingly scarce capital resources in strategies which have less potential, less certainty and longer delayed payoffs than the proposed alternative strategy emphasizing a national program for energy efficient building. (American Institute of Architects, 1975.)

One of the characteristics of modern civilization is the increasing rate of energy utilization on a per capita basis. In the residential sector, the increasing rate of energy utilization per capita is due primarily to the increasing demand for year round climate control and for energy usage in the residential sector. The consumption of energy by the residential sector represents approximately 20 percent of our national energy budget - an estimated 3 billion barrels of crude oil each year.

Studies directed to reducing the amount of energy consumed in housing has suggested that a 25% to 35% reduction in the heating component is possible by making fundamental construction improvements (e.g.: upgrading insulation, adding weatherstripping and double glazing) and by being careful in the use of energy (e.g.: by setting back thermostats).

As important as 25% - 35% savings maybe they can be significantly extended if one is willing to go beyond the "fundamental construction improvements" above and select alternative energy-efficient household systems. This requires that the builder fully understand natural energies such as the sun and wind, and be able to respond to them in all phases of planning design and construction.

CHARACTERISTICS of EED

Planning Ahead

Whether building a new home or a standard subdivision lot or a hillside in the county, energy conservation and energy efficiency begins with land planning, and will work best when energy efficient/conservation has been a consideration from the beginning.

Site Planning

The building site is an extremely important EED consideration. The conditions and characteristics of the building site will influence the dwelling design. Existing vegetation, geology, topography, and climate are the primary site characteristics considered during site planning and design.

Site planning for the utilization of solar energy is concerned with two major issues: 1) access to the sun, and 2) location of the building on the site to reduce its energy requirement. The placement and integration of the dwelling on the site in response to these concerns entails numerous decisions made at a variety of scales. Other site selection factors which should be analyzed and evaluated carefully before building are as follows.

GEOGRAPHY OF AREA SURROUNDING THE SITE

- the daily and seasonal path of the sun across the site
- the daily and seasonal wind-flow patterns around or through the site
- the presence of earthforms which may block the sun or wind
- the presence of low areas where cold air could settle

TOPOGRAPHY OF SITE

- steepness of the slope - can it be built upon economically
- the presence of slopes beneficial or detrimental to energy conservation and solar energy utilization

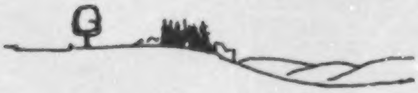


Figure 6.1 (Adams)

EXISTING VEGETATION (major factor)

- size, variety and location of vegetation which would impair solar collection
- building sites which would disturb existing vegetation to a minimum
- size, variety and location of vegetation which would assist in energy conservation

PRECIPITATION PATTERNS ON THE SITE

- fog movement, collection or propensity patterns
- snow drift and collection patterns
- frost "pockets"

ORIENTATION OF SLOPES ON THE SITE

- south-facing slopes for maximum solar exposure
- west-facing slopes for maximum afternoon solar exposure
- east-facing slopes for maximum morning solar exposure
- north-facing slopes for minimum solar exposure

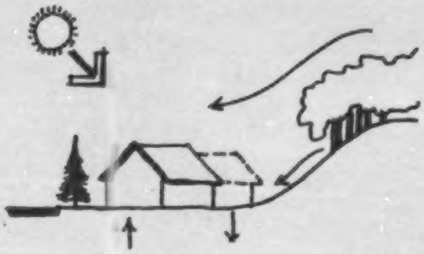


Figure 6.2 (Adams)

SOLAR RADIATION PATTERNS ON THE SITE (major factor)

- daily and monthly
- seasonal
- impediments (e.g., vegetation that may cover the site or shadow buildable areas on the site)

Figure 6.3 (Adams)

WIND PATTERNS ON THE SITE (major factor)

- daily and monthly
- seasonal
- impediments Ie.g., thick vegetation or underbrush that may block air movement on or through the site)

TEMPERATURE PATTERNS ON THE SITE

- daily and monthly
- seasonal
- warm areas
- cold areas

Tools for site analysis include air photos, topographic maps, climatic charts or direct observations on the site. Site selection at whatever scale must take into account the distinctive characteristics of the major climatic regions of the United States. Once the data is collected and organized, it can be used to evaluate, rate and eventually select a specific location or site for the placement of the dwelling, solar system, and other site related activities.

The Sun

One of the two major factors influencing the energy used on any site is the sun. The other is wind. The sun delivers wanted energy free of charge during cool periods, but it also at times provides excess heat which may be removed at great cost in energy.

But let's look at the simple things first.

While the sun always rises, reaches its zenith and sets in the same points of the compass, it varies geographically, being higher in the sky in southern than in northern latitudes. Season variation also occurs, of course, because of the precession of the earth's axis, and the sun is higher in the sky during the summer and lower in winter (reverse in the southern hemisphere.) So much for the sun.

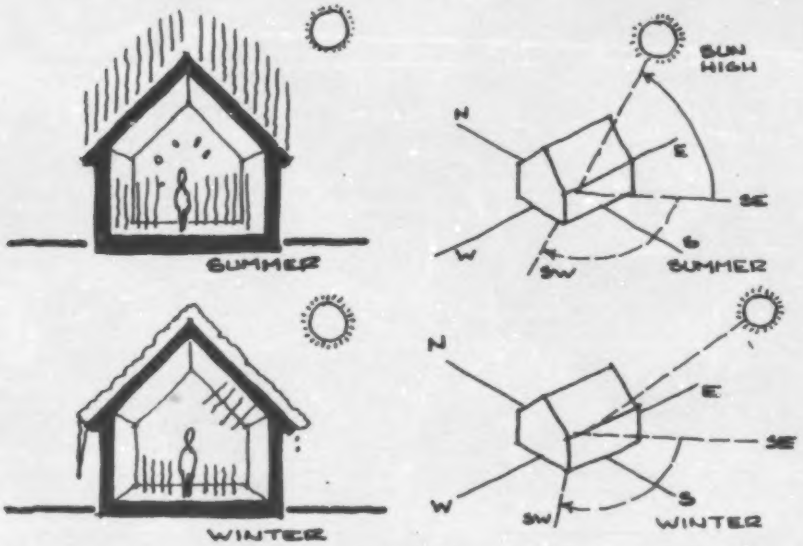


Figure 6.4 (Adams)

The Wind

The second major factor, the wind, deprives you of heat during cool periods but is most helpful in removing unwanted heat in times of excess warmth.

In our hemisphere the prevailing windes generally blow from west to east. But seasonal and regional variations may find warm and often moist winds blowing from the south, and cold, dry winds from the north. These patterns combine to establish southwesterly and northwesterly winds which often are identified with a certain season.

Other wind patterns derive from the weather characteristics of a region. Thus we sometimes experience cold blizzards from the north and northeasters from the ocean.

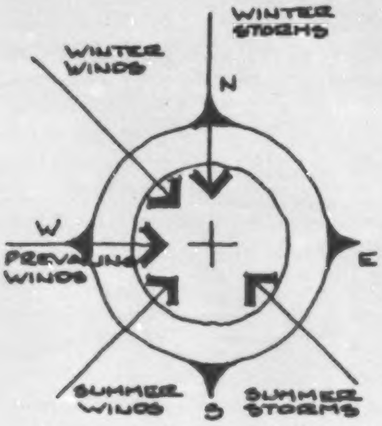
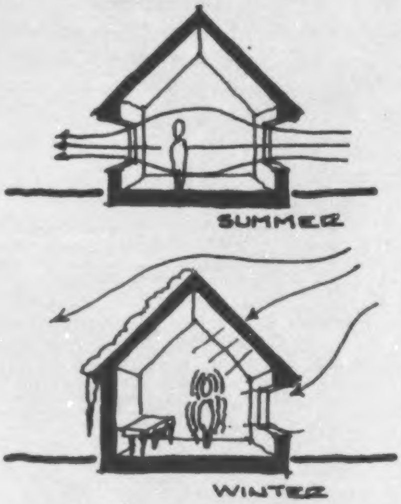


Figure 6.5 (Adams)



Wind patterns are affected also by large geographic features. Major mountain ranges will alter the direction of prevailing winds; large bodies of water will make them warmer or colder; large open expanses will allow them to reach full velocity; broken terrain will dissipate or scatter these effects.

It is important to know about all these variations of wind patterns where you plan to settle. The local Weather Bureau may help establish them, as will conversations with people whose livelihood depends on weather (farmers, fishermen, ranchers, woodsmen).

Using this wind information and a simple pocket compass you will be able to make some highly-educated guesses as to how overall climate condition will affect your potential home.

Your localized summary may look like this:

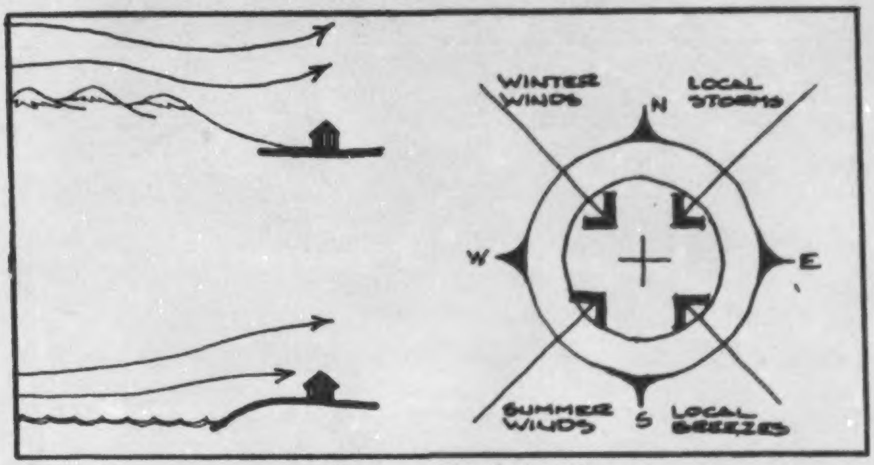


Figure 6.6 (Adams)

Climate

Your next step is to see how the physical features of a site will be affected by or perhaps will modify general climatic conditions.

A surface most nearly to a right angle to the sun's rays will absorb the most energy from the sun. Thus, given something less than a sun directly overhead, a sloped ground surface will absorb more than a flat one. When the sun is at its highest point, it will be most nearly at a right angle to the ground, so a slope facing south (in the Northern Hemisphere) absorbs most of all. Slopes that face east and west therefore will get less heat from the sun, and one facing north will get the least. Flat land makes little discernible difference. So much again for the sun.

Surfaces directly exposed to the wind will receive its full force. Surfaces sloping toward the wind will be all the more affected. Exposure is made more severe as wind velocities are increased in being compressed by the topography. Steeply-sloped or broken terrain will cause turbulence or eddies. A site on broad expanses of flat area, such as prairies or adjacent to lakes or oceans, are exposed to the full sweep of the winds.

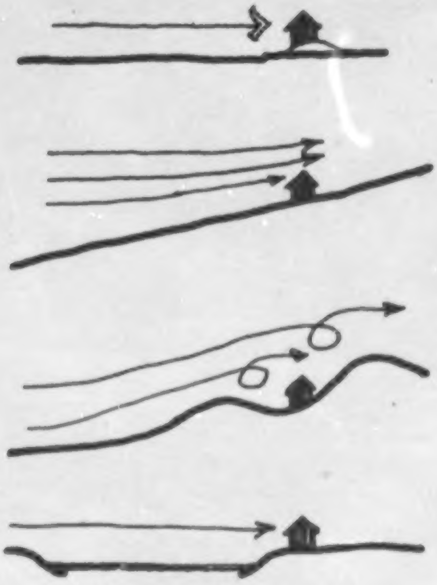


Figure 6.7 (Adams)

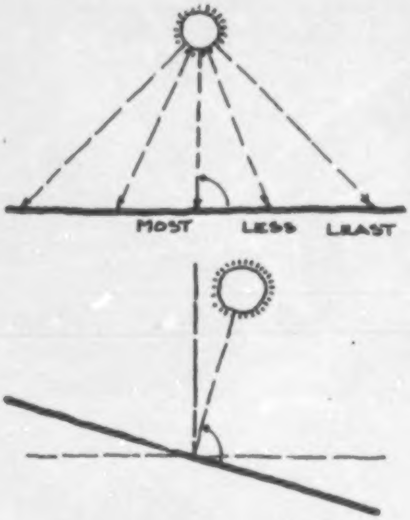


Figure 6.8 (Adams)

CONCLUSIONS-CLIMATE

SUN

South-facing building sites are warm.
North-facing building sites are cold.
East-facing building sites get early morning, warming sun.
West-facing building sites often get hot, afternoon sun.

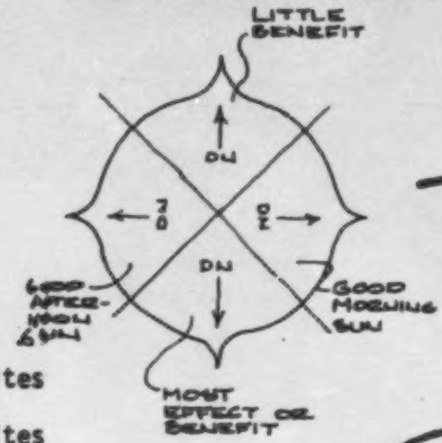

LITTLE BENEFIT
DN
DN
DN
DN
GOOD AFTER-NOON SUN
GOOD MORNING SUN
MOST EFFECT OR BENEFIT

Figure 6.9
(Adams)

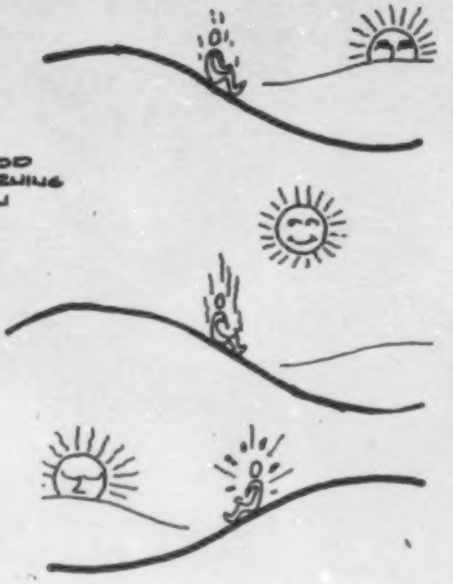
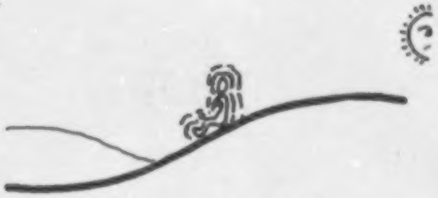


Figure 6.10
(Adams)



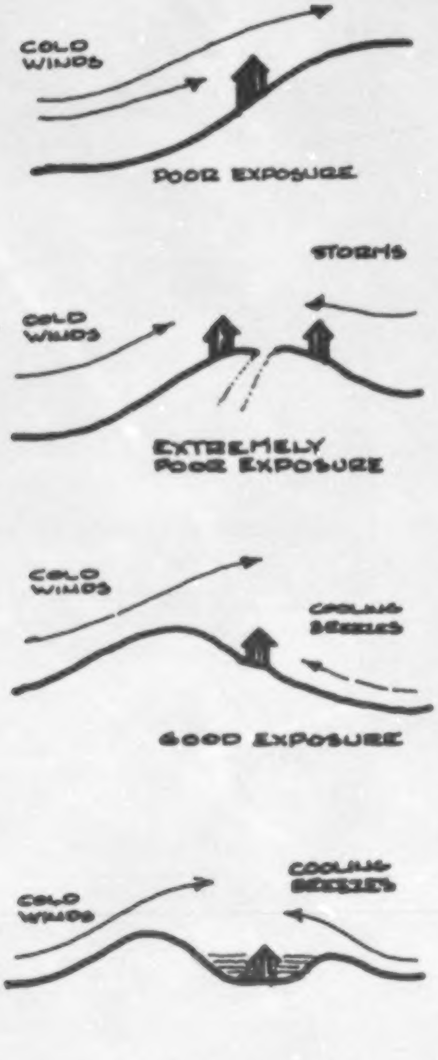

COLD WINDS
POOR EXPOSURE
STORMS
COLD WINDS
EXTREMELY POOR EXPOSURE
COLD WINDS
COOLING BREEZES
GOOD EXPOSURE
COLD WINDS
COOLING BREEZES

Figure 6.11 (Adams)

WIND

Hill tops, ridges, profiles and higher elevations have more exposure to the wind, and will be cooler in cold seasons, cooler in warm.

Slopes facing away from prevailing winds are sheltered.

Slopes facing toward prevailing winds are cooler. Valley bottoms will be warmer in the warmer seasons, cooler in cold seasons.

Sites on flat expanses are open to full sweeps of winds. Air temperature near large bodies of water will be tempered by the wind.

On a smaller scale a mountain, hills or even smaller knolls will provide shelter from a cold wind on the down-wind side, or will effectively cut off the refreshing coolness of a summer breeze.

Landscape

Proper landscaping of a house site can plan an important role in overall energy efficiency. Trees and other vegetation help reduce heating and cooling costs, muffle noise, purify the air, and add much to the beauty and actual worth of a finished home.

USE VEGETATION TO INCREASE THERMAL PROTECTION

Whenever possible, let natural vegetation help insulate and cool the house. In this climate shrubs and trellis vines can be planted on all sides of a house to reduce the amount of heat gain on wall surfaces. In fact, some experts report that vegetation used in this way can increase the insulation value of a wall by as much as 30%.

Deciduous trees planted on the south side of the house can help filter out the sun's warmth in the summer. In the winter, when the trees lose their leaves, the sun shines through and helps warm the home. Both deciduous and evergreen trees are particularly helpful for shading east and west exposures. Ponds, water foundations and ground cover on the east, west and south sides of the house help lower the temperature of the surrounding air.

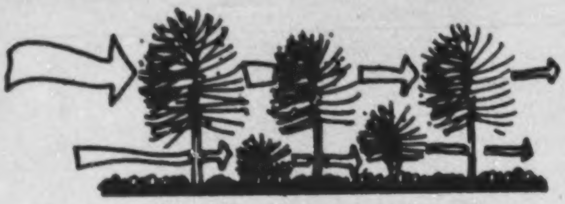
PROTECT VEGETATION DURING CONSTRUCTION

Whenever possible, site the house to save large trees, and remove only those trees which interfere with laying the foundation of the building. Protect all remaining vegetation from damage and abuse. Route underground utility and sewer lines for minimal damage to the root systems of large trees.

Climatic Regions of the U.S.

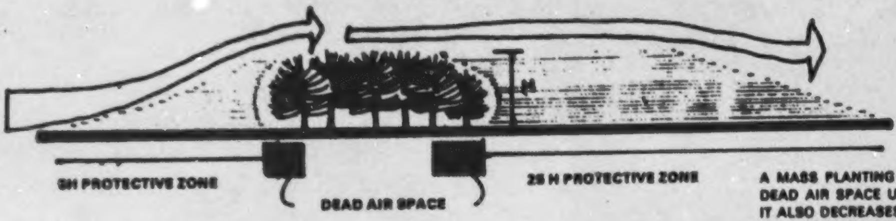
Four broad climatic zones are to be found in the United States: cool, temperate, hot-arid, and hot-humid. The areas of the United States which exhibit the general characteristics associated with each zone are shown below. The boundary between regions is not as abrupt as indicated. Each different climatic region merges gradually and almost invisibly into the next one.

The climatic characteristics of each region are not uniform. They may vary both between and within regions. In fact, it is not unusual for one region to exhibit at one time or another the characteristics associated with every other climatic region. However, each region has an inherent character of weather patterns that distinguishes it from the others. A brief description of the four climatic zones will identify the general conditions to which solar dwelling and site designs in those regions must be responsive.

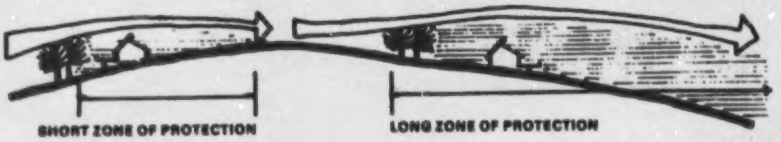


MULTIPLE BRAKING EFFECT

MULTI-LAYERED VEGETATION INCLUDING CANOPY TREES AND UNDERSTORY TREES OR SHRUBS PROVIDES A MULTIPLE BRAKING EFFECT, SUBSTANTIALLY DECREASING THE WIND VELOCITY MOVING OVER A SITE.



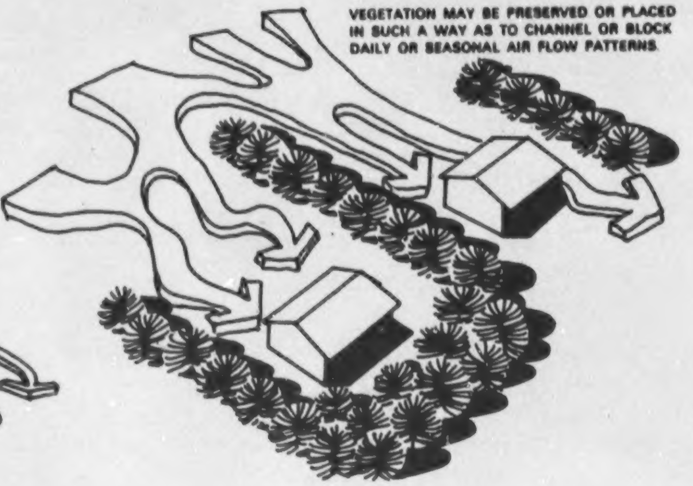
A MASS PLANTING OF TREES PROVIDES A DEAD AIR SPACE UNDER AND AROUND ITSELF. IT ALSO DECREASES THE AIR VELOCITY 5 TIMES ITS HEIGHT TO WINDWARD AND 25 TIMES ITS HEIGHT TO LEEWARD OF THE PLANTING.

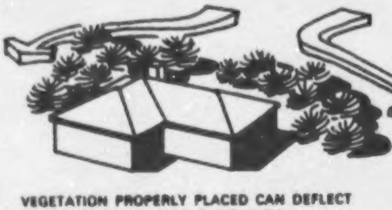


PLANTING ON THE LEEWARD SIDE OF A HILL SUBSTANTIALLY INCREASES THE DOWNWIND ZONE OF REDUCED AIR VELOCITY, WHILE PLANTING ON THE WINDWARD SIDE CORRESPONDING DECREASES THE ZONE.

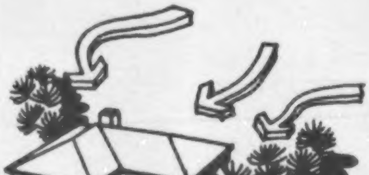
FENCES, WALLS OR VEGETATION CAN BLOCK NATURAL AIR FLOW PATTERNS. CARE MUST BE TAKEN DURING SITE DESIGN TO PROVIDE THE NECESSARY VISUAL CONTROL WHILE AVOIDING ADVERSE CLIMATIC CONDITIONS. AS COOLER AIR FLOWS DOWNHILL IN THE EVENING, FENCES, WALLS OR PLANTINGS SHOULD NOT UNINTENTIONALLY DAM THIS FLOW AND THUS CREATE A COLD AIR POCKET WHERE IT IS NOT WANTED.

VEGETATION MAY BE PRESERVED OR PLACED IN SUCH A WAY AS TO CHANNEL OR BLOCK DAILY OR SEASONAL AIR FLOW PATTERNS.

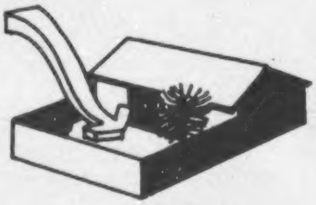




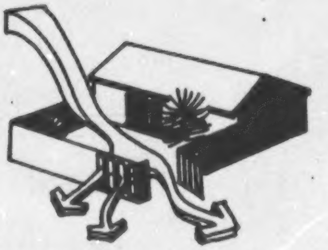
VEGETATION PROPERLY PLACED CAN DEFLECT RATHER THAN DAM COLD AIR FLOW



DWELLING UNPROTECTED FROM COLD AIR FLOW



COLD AIR TRAPPED BY FENCE



FENCE DESIGN CAN PROVIDE FOR COLD AIR DRAINAGE

Figure 6.12

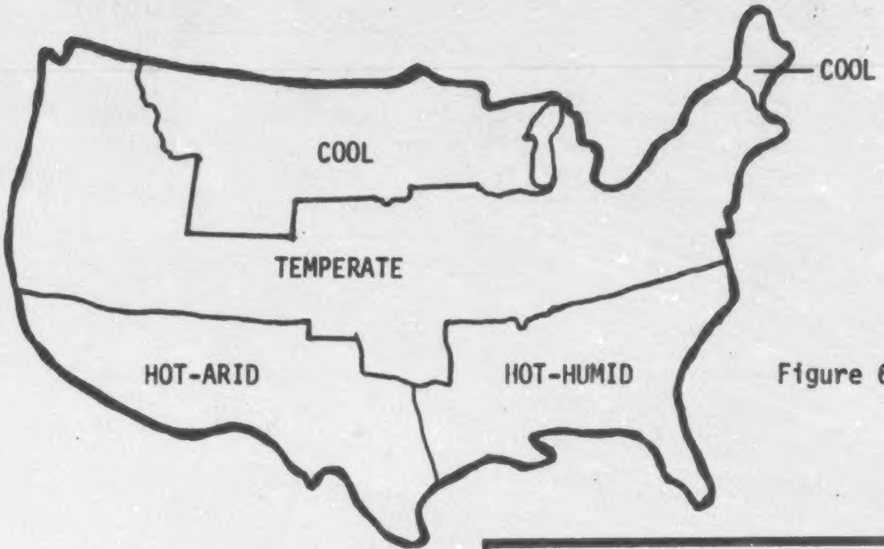
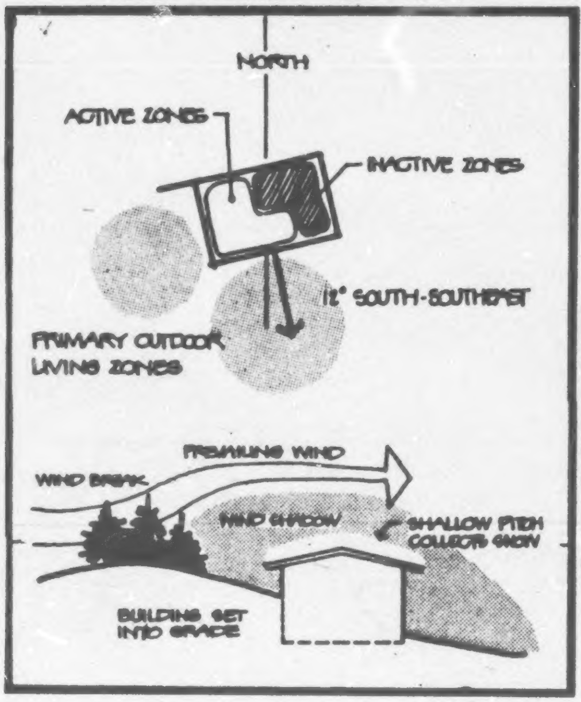
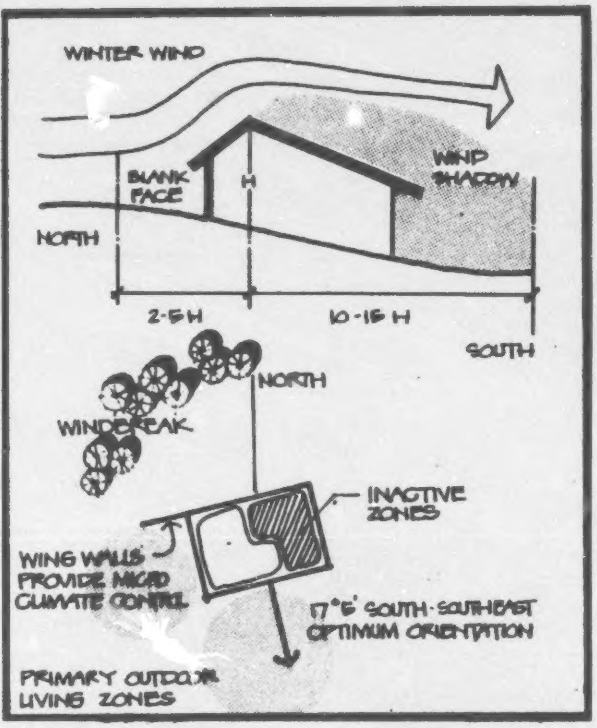

COOL
COOL
TEMPERATE
HOT-ARID
HOT-HUMID

Figure 6.13

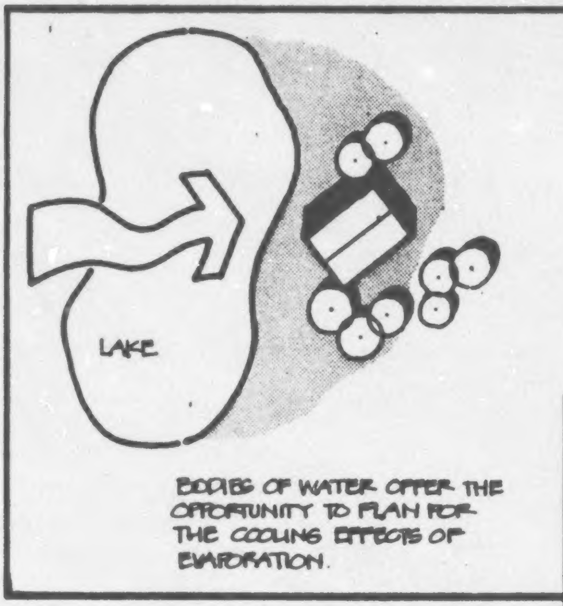
COOL REGIONS: A wide range of temperature is characteristic of cool regions. Temperatures of minus 30°F (-34.4°C) to plus 100°F (37.8°C) have been recorded. Hot summers and cold winters, with persistent winds year round, generally out of the NW and SE, are the primary identifiable traits of cool regions. Also, the northern location most often associated with cool climates receives less solar radiation then southern locations.


NORTH
ACTIVE ZONES
INACTIVE ZONES
12° SOUTH-SOUTHEAST
PRIMARY OUTDOOR LIVING ZONES
PREVAILING WIND
WIND BREAK
WIND SHADOW
SHALLOW PITCH COLLECTS SNOW
BUILDING SET INTO GRADE

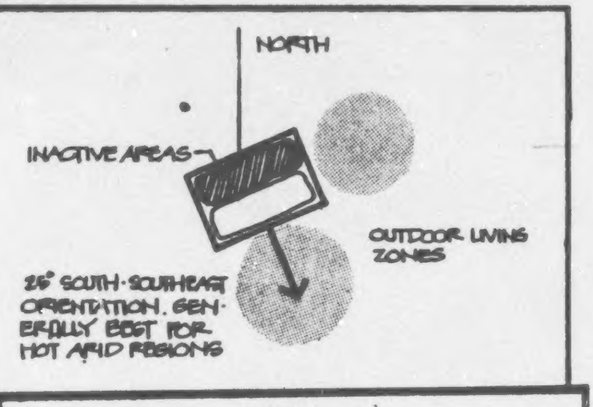

WINTER WIND
BLANK FACE
H
WIND SHADOW
NORTH
2-5 H
10-15 H
SOUTH
NORTH
WINDBREAK
INACTIVE ZONES
WING WALLS PROVIDE MICRO CLIMATE CONTROL
17°5' SOUTH-SOUTHEAST OPTIMUM ORIENTATION
PRIMARY OUTDOOR LIVING ZONES

TEMPERATE REGIONS: An equal distribution of overheated and underheated periods is characteristic of temperate regions. Seasonal winds from the NW and S along with periods of high humidity and large amounts of percipitation are common traits of temperate regions. Intermittent periods of clear sunny days are followed by extended periods of cloudy overcast days.

HOT-ARID REGIONS: Hot-arid regions are characterized by clear sky, dry atmosphere, extended periods of overheating, and large diurnal temperature range. Wind direction is generally along an E-W axis with variations between day and evening.

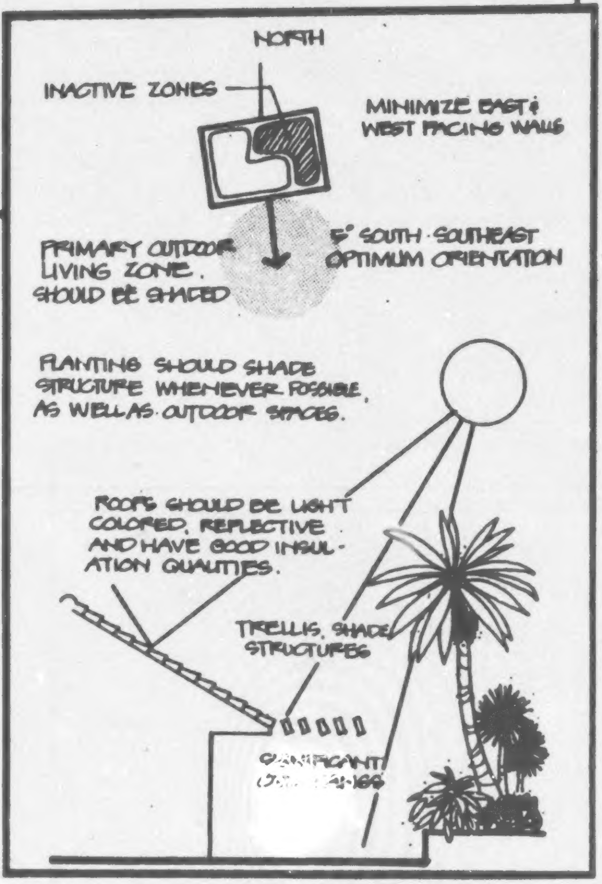


BODIES OF WATER OFFER THE OPPORTUNITY TO PLAN FOR THE COOLING EFFECTS OF EVAPORATION.


NORTH
INACTIVE AREAS
OUTDOOR LIVING ZONES

25° SOUTH-SOUTHEAST ORIENTATION. GENERALLY BEST FOR HOT ARID REGIONS

HOT-HUMID REGIONS: High temperature and consistent vapor pressure are characteristics of hot-humid regions. Wind velocities and direction vary throughout the year and throughout the day. Wind velocities of up to 120 mph may accompany hurricanes which can be expected from E-SE directions.


NORTH
INACTIVE ZONES
MINIMIZE EAST & WEST FACING WALLS
PRIMARY OUTDOOR LIVING ZONE. SHOULD BE SHADED
5° SOUTH-SOUTHEAST OPTIMUM ORIENTATION
TRELLIS, SHADE STRUCTURES
SIGNIFICANT OVERHANGS

PLANTING SHOULD SHADE STRUCTURE WHENEVER POSSIBLE, AS WELL AS OUTDOOR SPACES.

ROOFS SHOULD BE LIGHT COLORED, REFLECTIVE AND HAVE GOOD INSULATION QUALITIES.

Each climatic region has its own distinctive characteristics and conditions that influence site planning and dwelling design for solar energy utilization and for energy conservation. The following chart suggests the general objectives of site planning and dwelling design for each climatic region as well as some methods for achieving these objectives. The chart reflects the seasonal trade-offs made between climatic optimums.

Objectives	Cool	Temperate	Hot Humid	Hot Arid
Adaptations	Maximize warming effects of solar radiation. Reduce impact of winter wind. Avoid local climatic cold pockets.	Maximize warming effects of sun in winter. Maximize shade in summer. Reduce impact of winter wind but allow air circulation in summer.	Maximize shade. Maximize wind	Maximize shade late morning and all afternoon. Maximize humidity. Maximize air movement in summer.
Position on slope	Low for wind shelter	Middle-upper for solar radiation exposure	High for wind	Low for cool air flow
Orientation on slope	South to Southeast	South to Southeast	South	East-southeast for P.M shade
Relation to water	Near large body of water	Close to water, but avoid coastal fog	Near any water	On lee side of water
Preferred winds	Sheltered from North and West	Avoid continental cold winds	Sheltered from north	Exposed to prevailing winds
Clustering	Around sun pockets	Around a common, sunny terrace	Open to wind	Along E-W axis, for shade & wind
Building Orientation	Southeast	South to Southeast	South, toward prevailing wind	South
Tree forms	Deciduous trees near bldg. Evergreens for windbreaks	Deciduous trees nearby on west. No evergreens near on south	High canopy trees. Use deciduous trees near building	Trees overhanging roof if possible
Road orientation	Crosswise to winter wind	Crosswise to winter wind	Broad channel, E-W axis	Narrow, E-W axis
Materials coloration	Medium to dark	Medium	Light, especially for roof	Light on exposed surfaces, dark to avoid reflection

Table 6.I Site Orientation Chart

THE BASIC STRUCTURE

A house should be built to last. Precious resources should not have to be used to destroy a building and construct a new one after only fifty years. A little more expenditure to ensure the durability of a house will ultimately save both resources and money. Local materials, such as wood and stone, should be used wherever possible. This reduces the energy required to produce the materials and transport them to the site.

Also, consider payback period of materials. Does the material cost more than it is worth? Is there an alternative? An example is the rapid rise in plywood costs. In some areas, it is less expensive to use boards rather than plywood. If the cost is out of line, develop new ideas and methods or reintroduce old construction methods.

Size and Shape

The heat transmission through a building is affected both by the composition of the walls and ceiling and by the amount of exposed surface area. Minimum surface area of exterior walls and ceiling should be used to enclose a given amount of floor living area.

A simple square or rectangular floor plan is the most economical to build. A house with many protrusions costs more and increases the surface area exposed to outdoor conditions relative to the living area provided.

The potential for heat loss is greater from a single-story rectangular building than it is from a single-story square structure with the same amount of floor living area. For example, a house that is 24 feet wide and 54 feet long has about 8 percent more exposed exterior wall area than a house that is 36 feet wide and 36 feet long. The floor area and ceiling area are the same in both cases.

Comparison of single-story vs. two-story houses requires consideration of both the amount of exterior wall and ceiling areas in each case and the amount of insulation incorporated into the walls and ceiling. For example, a two-story house 28 feet wide and 28 feet long has the same living area on two floors as a single-story house 28 feet wide and 56 feet long. The two-story structure will only have half as much ceiling area as the single-story house, but it will have one-third more exterior wall area. With 8 inches of insulation in the ceiling and 3-1/2 inches in the exterior walls, the heat loss during the winter can be expected to be about 5 percent more from the two-story house than from the single-story house.

Large amounts of insulation can be easily incorporated into the ceiling separating living space from the unheated attic, but there is space for only 3-1/2 inches of insulation in the typical exterior wall. Improving the thermal efficiency of exterior walls could shift the advantage to two-story houses. Two-story buildings do have only half as much foundation and roof area compared to single-story houses with the same floor area, which will reduce the costs of these materials.

The size of a house depends on the life style and number of occupants living in shelter. For maximum energy efficiency however, the size of the house should be as small as possible. An optimum size is approximately 1200 sq. ft. The smaller the square footage, the less air conditioning will be needed to provide a comfortable living environment. A smaller home also reduce the cost of construction.

Site Orientation

In extreme climates of either hot or cold, compact design is most important. In cold climates, orient houses south if possible and if appropriate, use proportionally more glass on the south wall and shade it with the right amount of overhang to reduce heat gain in the summer. In hot, arid climates, consider a design or orientation that will buffer against hot breezes.

Garages and carports can help reduce the energy load. If you have a choice, in cold climates, put attached garages on the north, northeast, or northwest exposures to serve as a buffer zone against cold winds. In hot climates, put the attached garages or carports on the east or west walls of the dwelling. Garages insulate against the sun's heat and carports can neatly serve to shade east and west windows, theregy reducing heat gain.

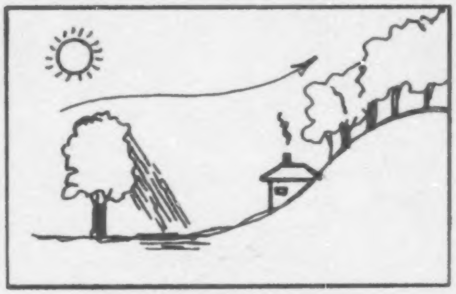


Figure 6.19 (Adams)

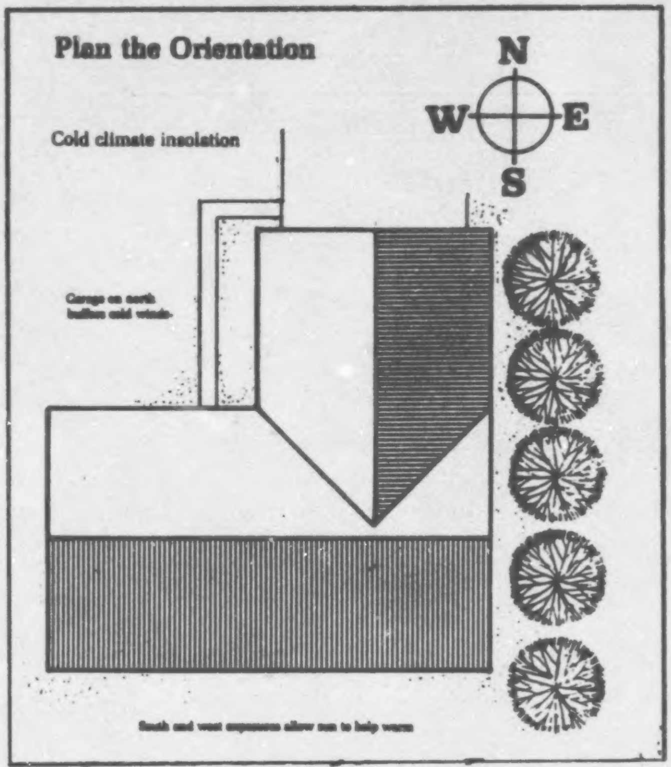

Plan the Orientation
N
W
E
S
Cold climate insolation
Garage on north buffers cold winds
South and west exposures allow sun to help warm

Figure 6.18 (Owens/Corning)

Houses are not typically built as completely underground structures. But houses built on sites sloping to the south or east can realize substantial benefits from the insulation capacity of the soil for example a house built into a hill on a south facing slope will have minimum exposure for heat loss on the north during the winter and maximum exposure for solar gain on the south.

EARTH BERMING - In areas where basement construction is not used or where soil conditions or other problems preclude it, earth can be bermed against the side of the structure to reduce heat loss and heat gain through the exterior wall. At minimum, earth can be bermed up to the height of conventional window sills; this does not interfere with views or ventilation, and it has a minimal visual impact on the appearance of the house.

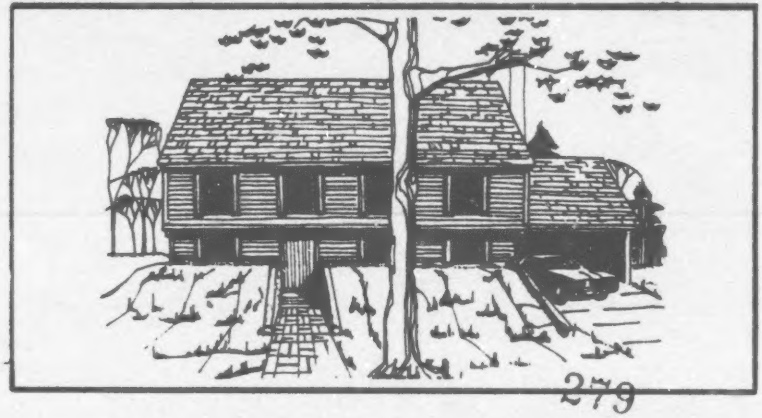


Figure 6.20

* Earth berming requires some care. The slope of the earth should not exceed 45°; a steeper slope will present problems in maintaining plantings as well as maintaining the necessary thermal benefits of the earth. Examine local codes, especially in relation to fire exists and ventilation. Also, before embarking on such an undertaking, a review of the latest research and consulting a qualified contractor and/or engineer is recommended.

Taking Advantage of the Shade

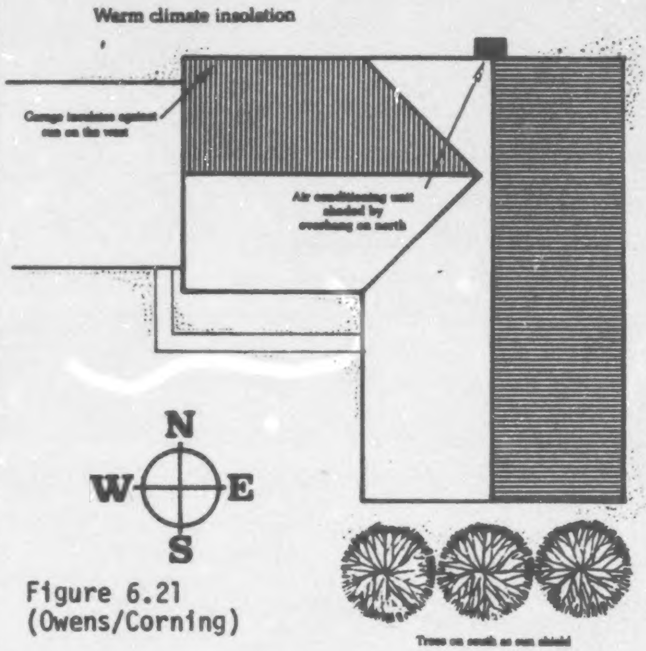

Warm climate insolation
Garage insulates against sun on the west
Air conditioning unit shaded by overhang on north
N
W
E
S
Trees on south as sun shield

Figure 6.21 (Owens/Corning)

Occasionally, it is possible to locate the dwelling or windows to take advantage of the shadows cast by existing trees to reduce solar heat gain in summer. Locating the air conditioning compressor where it will be shaded, particularly in the afternoon, by the house, trees, garage or carport will increase efficiency and reduce energy use.

Windows

Window Area and Glazing - Double glazing or storm sash will save energy in particularly cold climates. It can also be advantageous to use double glass and storm sash or triple glazing. Glazing can be equally useful in warm climates where air conditioning is the primary concern.

Thermal break type windows reduce heat loss. The window frames are basically metal with some less conductive material (like vinyl) sandwiched in between the outside metal frame units to cut down on the amount of cold transmitted through the metal. Wood window frames

Thermal Break Type Metal Windows

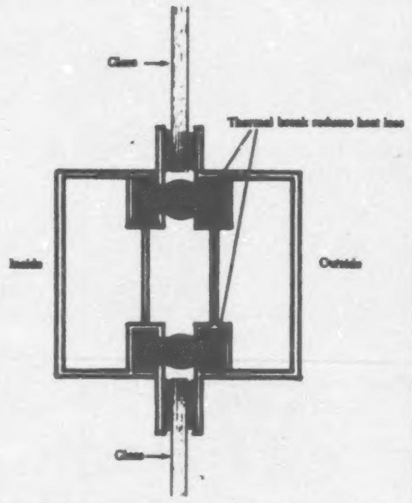

Glass
Thermal break reduces heat loss
Inside
Outside
Glass

Figure 6.22 (Owens/Corning)

conduct less heat than metal, and are now made with vinyl facings which reduce the likelihood of warpage over a period of time. Authorities disagree on the amount of heat conducted through the metal sash compared to wood sash, but in any event the thermal break type does reduce heat loss and condensation.

Window Infiltration

Tight Construction - Air infiltration around doors, windows and through other cracks in a major heat loss factor in any house and properly fitted windows can be the biggest single energy saver. A poor-fitting window without weatherstripping, for example, can allow 5-1/2 times as much air infiltration as an average fitting window that is weatherstripped. In terms of energy, the difference is most significant. Weatherstripping can significantly cut down on air infiltration even with a poorly fitted window, but the place to begin is still with a quality window, properly fitted.

Window Heat Gain

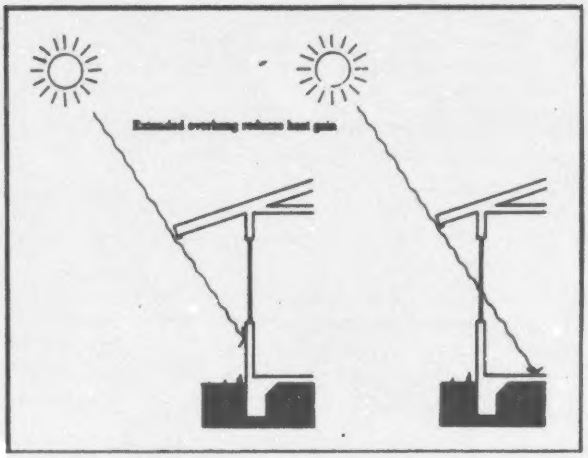


Figure 6.23 (Owens/Corning)

WINDOW SHADING - Shading southern exposure glass with an overhang is an important method of reducing heat gain in the summer-when the sun moves in its most vertical overhead arc-without impairing heat gain in the winter-when the sun moves in a souther arc. At the 35-degree latitude (North Carolina, Oklahoma, Las Vegas) a 32-inch overhand will completely shade a south floo floor-to-ceiling window during the summer and reduce the heat gain 50% on that glass. Properly sized overhangs can also permit solar heat gain in the winter heating season.

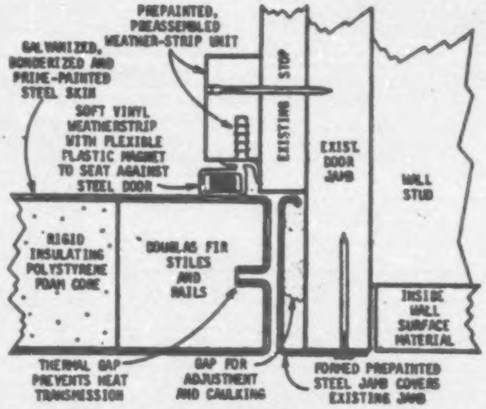
WINDOW LOCATION - Since the sun's rays are the most intense on the east and west, obviously it makes sense to keep window exposure on these sides to a minimum. If the window areas in our example house are rearranged so that only 10% (or 20 square feet) is facing the east, 10% west, and the other 80% divided equally between north and south walls, another 2,100 Btuh can be saved when double glazing or storm sash is used.

For winter heating it is imperative to keep north (or prevailing winter winds) faced windows to a minimum. When designing a home exclude window areas on this side as much as possible. Winter heat loss through existing windows on the north can be reduced through insulated shutters and other weatherization methods mentioned in Unit 3 of the PRIMER.

Doors

AIR INFILTRATION - Even a well fitted door allows as much air infiltration as a poorly fitted double-hung wood window. So fit becomes crucial. Wood doors double the problem due to warpage over a period of time.

INSULATED DOORS - The best approach is to consider installing well insulated and sealed doors. This will reduce air infiltration as well as insulate against the cold. Early foam steel doors were not much better energy savers than wood doors because the steel skin was one piece. As a result, the metal skin conducted heat out around the foam insulators. During very long temperatures, it was not uncommon to see frost form on side of the door. New designs have solved that problem by interrupting the steel skin around the edges of the door, forming a thermal break. In addition, steel doors can utilize magnetic weatherstripping of the type used on modern refrigerators and freezers. A flexible magnetic inside a plastic sheave of weatherstripping pulls the weatherstripping tight against the door whenever it is closed to provide an excellent seal against air infiltration.


PREPAINTED, PREASSEMBLED WEATHER-STRIP UNIT
GALVANIZED, BONDERIZED AND PRIME-PAINTED STEEL SKIN
SOFT VINYL WEATHERSTRIP WITH FLEXIBLE PLASTIC MAGNET TO SEAT AGAINST STEEL DOOR
STOP
EXISTING
EXIST. DOOR JAMB
WALL STUD
RIGID INSULATING POLYSTYRENE FOAM CORE
DOUGLAS FIR STILES AND RAILS
INSIDE WALL SURFACE MATERIAL
THERMAL GAP PREVENTS HEAT TRANSMISSION
GAP FOR ADJUSTMENT AND CAULKING
FORMED PREPAINTED STEEL JAMB COVERS EXISTING JAMB

This section of a foam-core Ever/Strait steel door shows the thermal break in steel skin and installation details. This is a door specifically designed for easy installation in remodeling situations. It's slightly undersize to fit into the old opening. Note the freezer-type magnetic weatherstripping.

Figure 6.24 (Hand)

VESTIBULE ENTRYWAYS - Adding storm doors, insulating a door, or installing an energy efficient door all help out losses while the door is closed, but none of these ideas help at all whenever the door is opened to enter or leave the home. Everytime the door swings open, in comes a blast of cold air. The solution here is an airlock or vestibule-a sort of enclosed porch with its own door. This arrangement keeps in the heat. Even when the outer door is open as one enters or exists, the inner door remains closed.

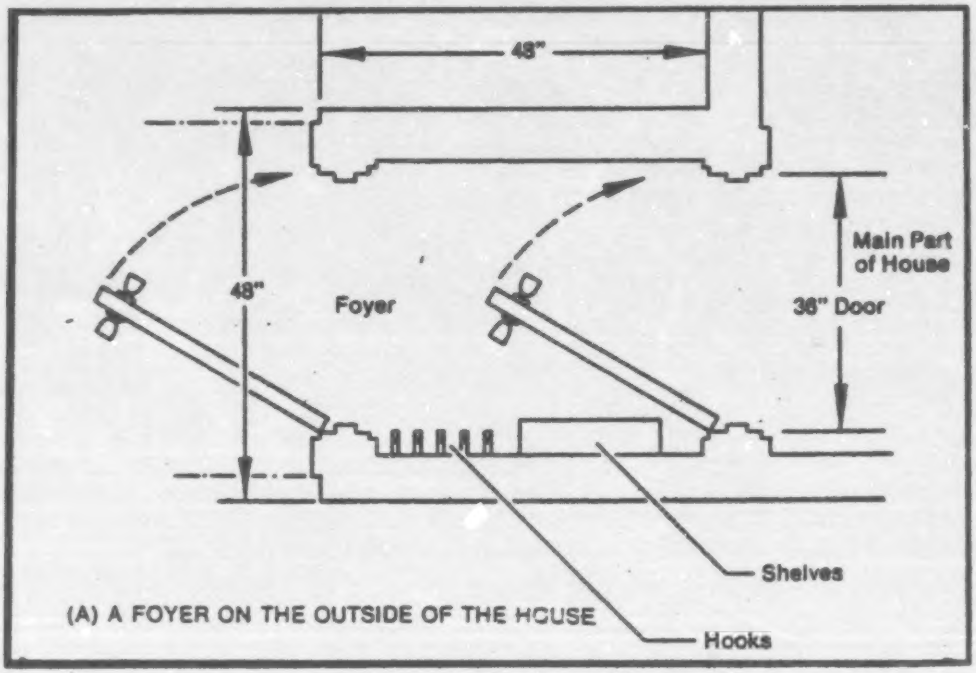

48"
48"
Foyer
Main Part
of House
36" Door
Shelves
(A) A FOYER ON THE OUTSIDE OF THE HOUSE
Hooks

Figure 6.25 (Eccli)

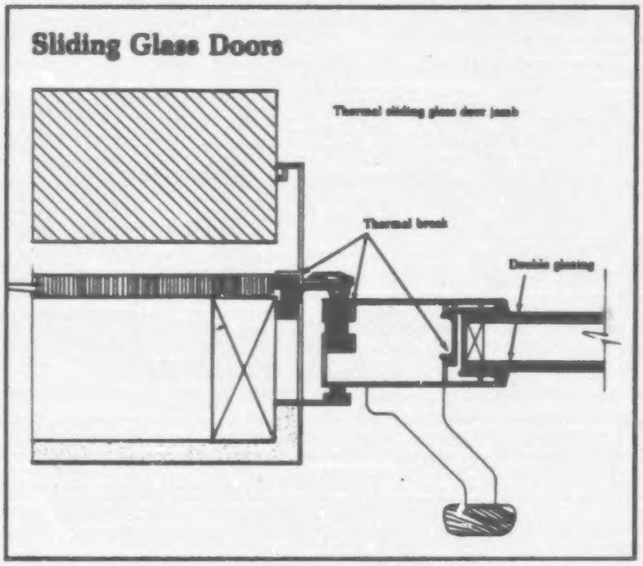

Sliding Glass Doors
Thermal sliding glass door jamb
Thermal break
Double glazing

Figure 6.26 (Owens/Corning)

SLIDING GLASS DOORS - Sliding glass doors with the large glass should be avoided in design. They are thermally inefficient and have large areas subject to possible air infiltration.

In those cases where sliding glass doors must be used to take advantage of solar gain, views etc., the make sure that they are placed on the southern exposure of the house and a thermal break type, double glazed door (as illustrated) is used. Properly weatherstripped and installed they are much more energy efficient than standard sliding glass doors.

Below the Floor

GRADING - Grade the ground surface around the house so there is an adequate slope for the surface water to drain away from the dwelling. This will help to keep the earth next to the foundation wall drier (and thus warmer) which will reduce heat loss through the wall.

PERIMETER INSULATION - If a 1600 sq. ft. house has a slab-on-grade, the use of one-inch by 12-inch wide edge or perimeter insulation will save approximately 4,000 Btuh compared to using no edge insulation. The use of two-inch by 24-inch wide edge insulation will save an additional 2,900 Btuh. If a perimeter heat duct system under the slab is used, the use of edge insulation becomes even more important and the heat loss savings even greater.

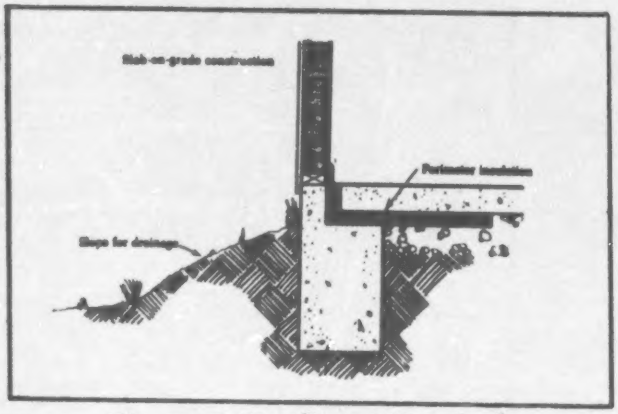

Slab-on-grade construction
Perimeter insulation
Slope for drainage
6.3

Figure 6.27 (Owens/Corning)

Crawl Spaces

UNHEATED CRAWL SPACES - Using closable vents and a vapor barrier ground cover-usually polyethylene film-if the crawl space is unheated will reduce heat loss even if the floors are insulated. The vents can be closed in winter to cut down on air infiltration. The purpose of a vapor barrier ground cover is to inhibit condensation which is likely to occur.

HEATED CRAWL SPACES - If you build with a heated crawl space, or plenum, use a vapor barrier on the ground and insulation on the perimeter walls.

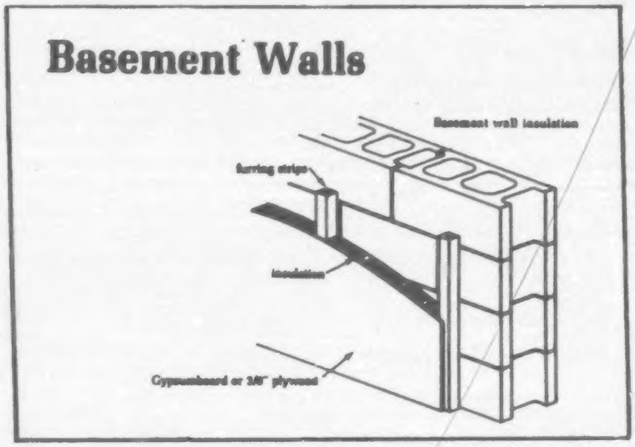

Basement Walls
Basement wall insulation
furring strips
insulation
Gypsumboard or 3/8" plywood

Figure 6.28 (Owens/Corning)

If we assume a 1600 sq. ft. house has a full basement and that the average basement wall exposure above grade is two feet, the heat loss through the typical 8-inch block wall would be 11,600 Btuh. Adding furring strips and R-3 (usually one inch) or masonry wall insulation covered with either gypsumboard or 3/8-inch plywood, reduces the heat loss 6,400 Btuh.

Using 2 x 2 furring strips and R-7 insulation will reduce heat loss an additional 1300 Btuh.

Walls and Framing

Framing Heat Loss

Considerably more heat is lost through the wood studs of a house than through the full-insulated spaces between the studs. For this reason, using 24-inch on center wall framing instead of 16-inch or some other closer interval will reduce heat loss about 700 Btuh in the 1600 sq. ft. home. Other lumber framing techniques that will be helpful are set forth in the NAHB Research Foundation's "Manual of Lumber and Plywood Saving Techniques."

Insulation

INCREASE THE 'R' FACTOR - As we all know, insulation in the walls makes a large difference in heat loss and heat gain, and the amount of difference depends on the insulation's 'R' rating, which is a measure of its ability to retard heat flow through the wall. Many builders and home buyers tend to compare insulations in terms of thickness, but the 'R' value is a more accurate comparison and is coming into more common use.

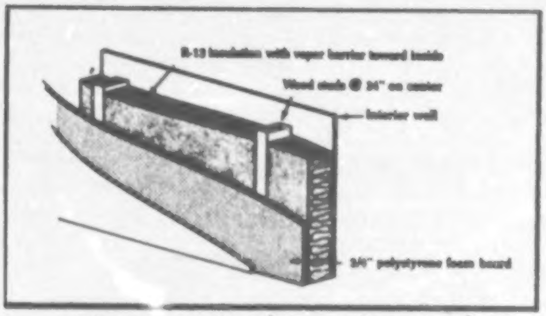
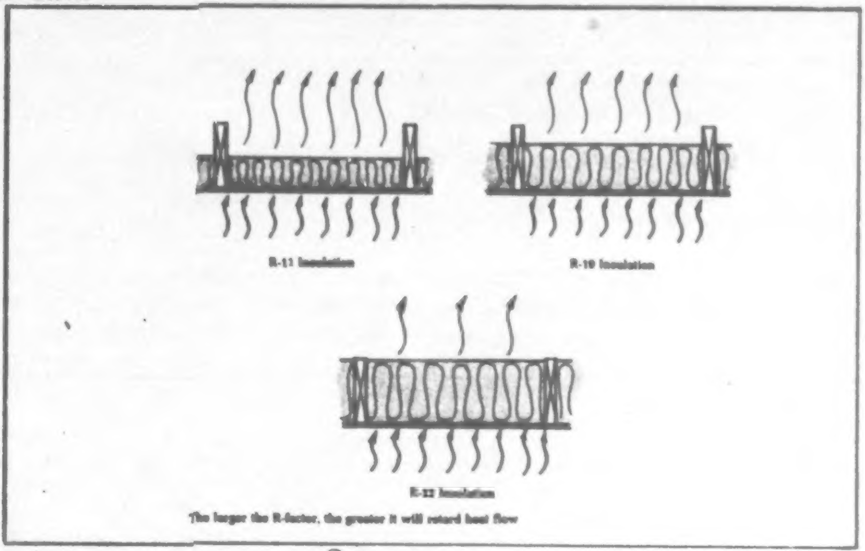

R-13 insulation with vapor barrier toward inside
Wood studs @ 24" on center
Interior wall
3/4" polystyrene foam board

Figure 6.29 (Owens/Corning)

R-11 insulation, in the 1600 sq. ft. example home, will save approximately 10,600 Btuh over uninsulated walls.

Figure 6.30
(Owens/
Corning)


R-11 Insulation
R-19 Insulation
R-22 Insulation

The larger the R-factor, the greater it will retard heat flow

INSULATION BOARD - If 3/4-inch foam polystyrene board is substituted for the 1/2-inch insulation board usually used, the heat loss would be reduced another 1,200 Btuh, but remember that the polystyrene board should be used in combination with insulation installed properly with the vapor barrier facing toward the inside of the house.

The Ceiling and Above

Insulation

The most important insulation in a house is in the ceiling and the choice of 'R' rating can make a major difference in the energy required to heat or cool a home.

BATTS - Using R-19 (6 inch) insulation rather than R-11 (3-1/2 inch) will save 3,500 Btuh. And using R-22 (about 7-inch) insulation will save almost another 700 Btuh.

BLOWN INSULATION - Blowing wool or blown insulation in the ceiling is often faster and more practical in terms of construction schedules but the thickness of the layer will be different to achieve the same 'R' value. Minimum thicknesses will be about 9 inches for R-19 and 10 inches for R-22. Check the bag label on blowing wool being used to assure proper coverage (bags per 1000 sq. ft.)

Ventilation

KEEPING THE AIR MOVING - Ventilation of attic and roof/ceiling spaces helps to lower air temperatures in these spaces in the summer. It also serves to allow moisture vapor to escape and thereby minimize the chance for wintertime condensation.

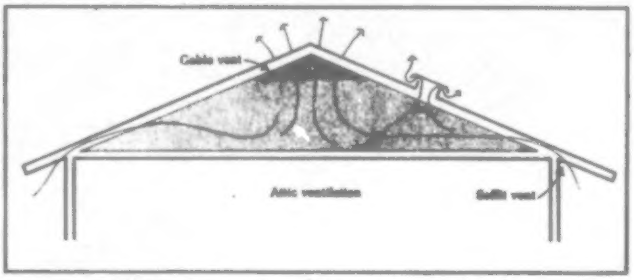


Figure 6.31 (Owens/Corning)

Even with insulation having a vapor barrier in the ceiling, good practice requires one square foot of attic ventilation area (or net free vent area) for each 300 squares feet of ceiling. This is a minimum. Studies indicate the need for even greater ventilation.

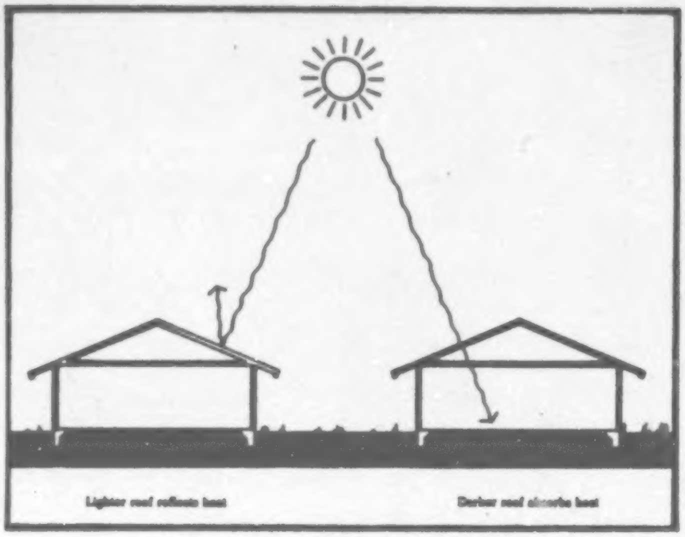


Figure 6.32 (Owens/Corning)

WARM WEATHER EFFICIENCY - We all know that dark colors tend to absorb heat while light colors reflect heat. So even with a well insulated ceiling, the color of the roof does make some differences, insofar as heat gain is concerned.

Attic Openings

Close attention to the places and spaces in an attic where air infiltration can add to the heating load of a home can make a significant difference.

Attic access doors should be weatherstripped. In addition, a piece of insulation board cut to the size of the attic door and tacked to the attic side of the door can materially improve the thermal characteristics of a panel or hollow core door.

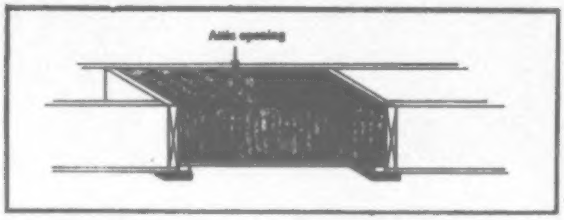


Figure 6.33 (Owens/Corning)

If there is an attic scuttle hole, weatherstrip it and insulate the back of the scuttle closure panel.

Stuff insulation around pipes, flues, or chimneys penetrating into the attic space, especially in cold climates.

Infiltration

LOWERING THE HEAT LOAD - The energy load required to heat infiltrating air from cracks, doors, windows, etc. can easily be the dominant thermal load factor, even when a house is well insulated. In the example 1600 sq. ft. home, reducing air infiltration from two to one air changes per hour can save 16,000 Btuh and reducing it to one-half air change per hour can save another 8,000 Btuh.

THE RIGHT SEAL IN THE RIGHT PLACE - Besides tightly-fitting windows and doors which have already been discussed, there are a variety of construction techniques which together can greatly reduce the amount of air infiltration in a home.

Construction Technique

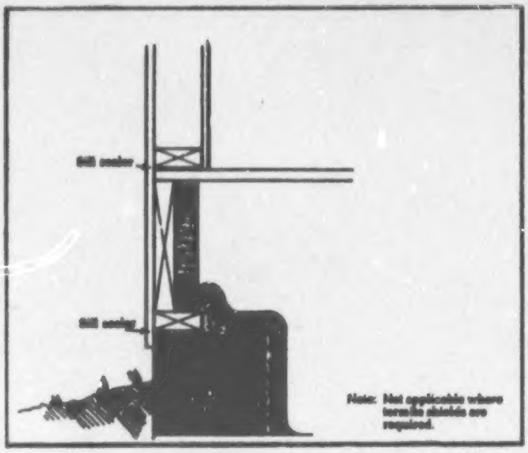


Figure 6.34 (Owens/Corning)

- In frame construction, sill sealer between the top of the foundation wall and the band joist or sill plate will reduce air infiltration.
- Sill sealer or flexible caulking between the bottom exterior wall plate and the rough floor can also make a large difference.
- Caulk outside cracks such as doors and windows.
- Instruct the contractor to wrap duct joints in non-conditioned spaces with duct tape to minimize leakage.
- Be sure sheathing is nailed tight to the framing to minimize air infiltration into the space between studs.
- Replace any wall sheathing damaged during construction so that the tightest possible fit is achieved uniformly.

Insulation Installation

GETTING THE RIGHT FIT

- Extend the ceiling insulation over the top of the top plate.
- Cut batts carefully to fit the narrow spaces between studs and leave enough surplus to staple the flanges. Butt the ends of batts tight against each other and shove them tight against the top and bottom plates in walls and cavities.

Often soffits under cantilevered floor constructions are either ignored or insulated with no particular care. Insulate soffits below cantilevered floors by cutting batt to the depth of the overhand-plus 10" x 12".

In basements, below grade living areas and unvented crawl space constructions, wedge or staple pieces of insulation along band joists and between floor joists where they meet band joists. R-19 should be used.

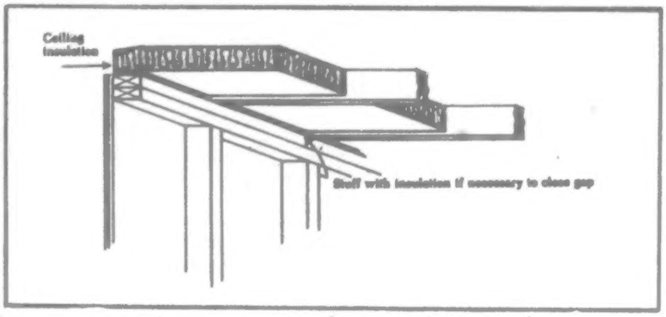


Figure 6.35 (Owens/Corning)

Tight fit at top and bottom plate and between old length pieces of insulation in the wall cavity is critical for effective thermal control. Batts with an attached vapor barrier should be carefully cut to fit the cavity then stapled along the flanges.

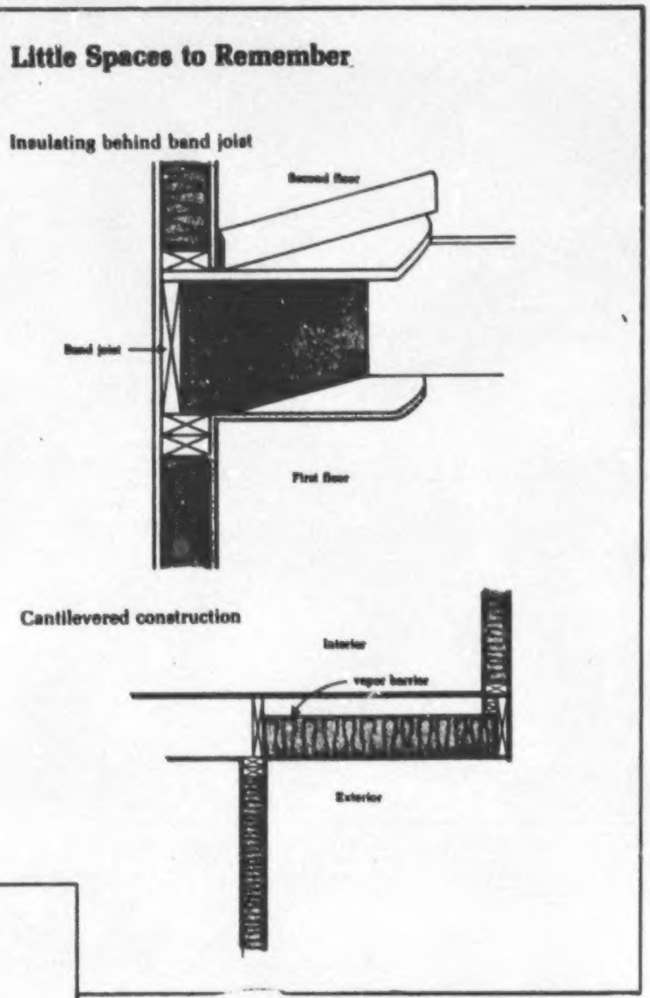
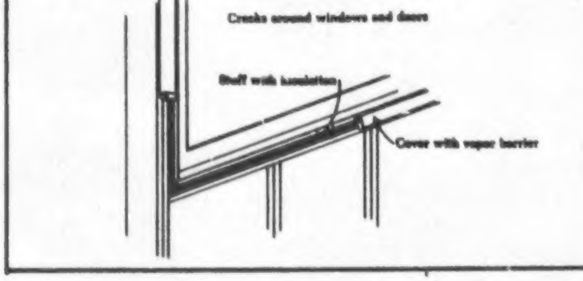

Little Spaces to Remember
Insulating behind band joist
Second floor
Band joist
First floor
Cantilevered construction
Interior
vapor barrier
Exterior

Figure 6.36
(Owens/Corning)

Insulate Behind the Band Joist and Underneath any Cantilivered Construction.

Figure 6.37 (Owens/Corning)


Cracks around windows and doors
Stuff with insulation
Cover with vapor barrier

- Stuff all cracks around doors and windows and small odd-shaped cavities with insulation and staple polyethylene (vapor barrier) over these areas.

- Insulate behind pipes, wires and electrical boxes in outside walls.

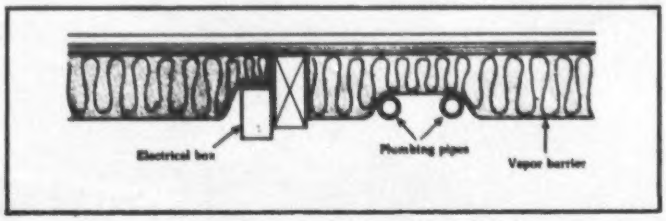

Electrical box
Plumbing pipes
Vapor barrier

Figure 6.38
(Owens/Corning)

Duct Insuldtion

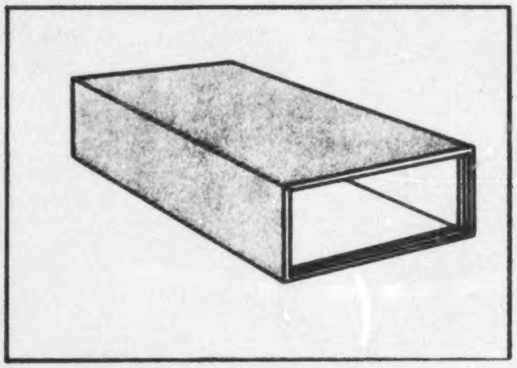


Figure 6.39 (Owens/Corning)

LOCATING THE DUCTS - Try to avoid ducts through non-conditioned spaces like attics. But if this is not possible, insulate the ducts well.

INSULATION AND FIBERGLASS DUCTS - Insulating ducts or using preformed Fiberglass ducts can significantly reduce heat loss.

In the example home, using pre-formed 2-inch flexible or 1-inch rigid duct board instead of 1-inch flexible type on the ducts in non-conditioned spaces will reduce the heat loss by about 3,400 Btuh. That's about a 30 percent increase in energy efficiency over the 1-inch flexible insulation.

For cooling, the 2-inch flexible or 1-inch rigid insulation will save 1,500 Btuh compared to the 1-inch flexible insulation assuming the ducts are in the attic space.

Household Equipment

AVOID OVERSIZING EQUIPMENT - One of the most important energy conservation measures that can be taken is to carefully determine the heat loss and heat gain requirements of a home and install equipment no larger than that required. Builders and consumers alike have often assumed that "bigger is better," but the truth is that oversized equipment results in short periods of operation, poor comfort conditions, lower seasonal efficiency and more energy consumption. Most local utility companies will happily help you figure the heating and cooling loads and the size equipment needed.

FURNACE LOCATION - For greatest efficiency, the furnace should be located near the center of the house to minimize the length of ducts and the distance the warmed air travels.

Require the HVAC subcontractor to install the furnace so that it will be relatively simple for the homeowner to change the filters on warm air furnaces. Clogged filters can substantially reduce fuel efficiency so filters should be changed at least once a month.

unit 7

ENERGY IN THE APARTMENT

by: M.P. Vogel

"How can I conserve energy? I'm concerned (I drive an energy efficient car), but I live in an apartment. Isn't energy conservation the responsibility of the building owner?" These questions represent the feelings of many apartment occupants.

The response? Yes, many energy conservation measures--storm windows and storm doors, insulation, separate meters, and thermostats, for example--are the responsibility of the building owner. There is much the tenant can do by becoming an energy advocate and by making efficient use of energy in the apartment.

Home Energy Conservation Primer

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  Others 8

RENTING AN APARTMENT

Some energy conservation measures are unique to apartments. Unlike single-family residences, apartments and condominiums are usually in rows or blocks, with several units in a building. This situation affords a good opportunity to save energy, since an apartment which is adjacent to another apartment will not be exposed to unheated space on that side; for example, an interior apartment has fewer surfaces exposed than an exterior or end apartment, so it will require less heating or cooling.

Another aspect of an apartment which affects the heating and cooling load is the level or floor on which it is located. Due to the fact that heat rises, apartments on upper floors tend to be warmer in the winter than those on lower floors; apartments on the lower level tend to be cooler in the summer. However, if natural ventilation is a major concern, a bottom floor or basement level may have little or no breeze.

Windows and doors in apartments are seldom protected with storm panels. This makes the number, size, and orientation of the windows and doors important. For example, an apartment in a cold climate with all its windows facing north will be much more difficult and expensive to heat than one with facing south. Care must also be taken to determine if the apartment will be shaded by other buildings or by vegetation.

Very little can be done to improve the exterior or shell of an apartment, so great care should be taken in its selection. If the apartment was previously occupied, it would be wise to ask the cost of heating and cooling in previous years. Usually high consumption could indicate an energy inefficient building.

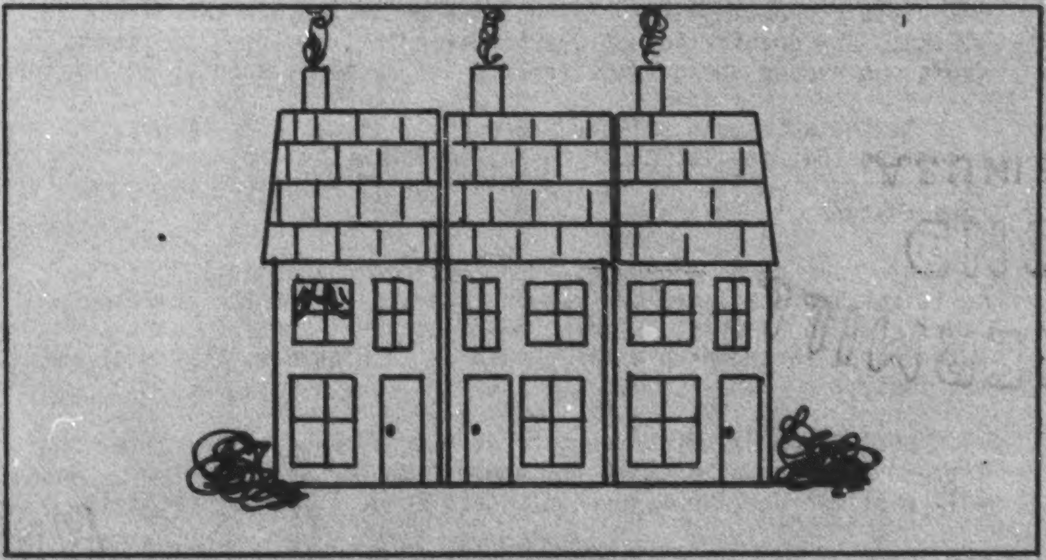

Figure 7.1 Row Houses

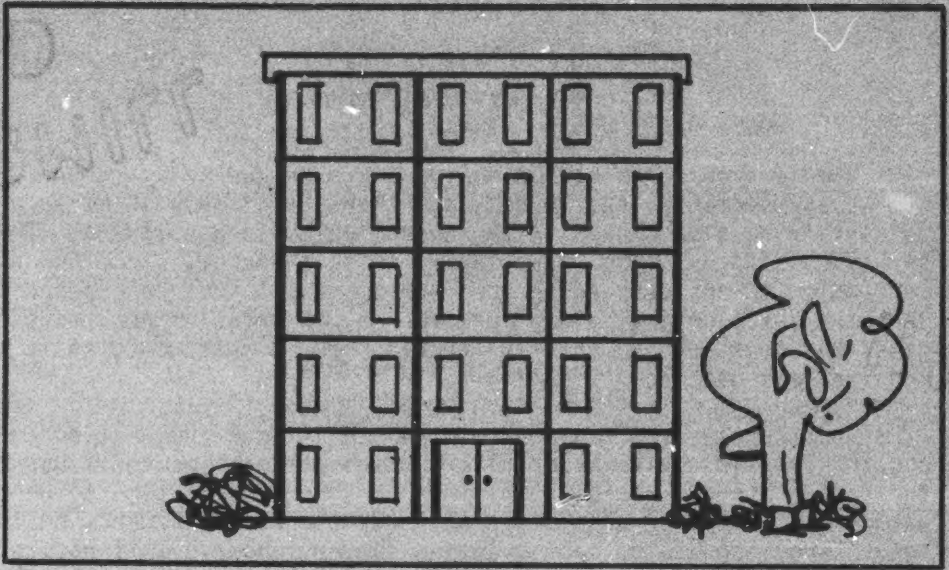

Figure 7.2 Apartment Complexes

ENERGY ADVOCACY

The most important thing one can do as an apartment occupant energy advocate is to convey to the owner of the building one's sentiments about the need to conserve limited energy resources. In person or by letter, point out how you believe energy is being wasted in the apartment building.

Are there drafts around windows and doors? Ask the building owner to weatherstrip windows and doors and to fill cracks with caulking compound. Also ask the owner to consider installing storm windows and storm doors if there are none on the building (4 or 6-mil plastic sheeting is an inexpensive but effective substitute for glass). The combination of weatherstripping, caulking and storm doors can reduce energy requirements and costs as much as 30%.

Is the apartment building adequately insulated? If not, recommend that insulation be installed in the ceiling and exterior side walls. This, too, has a positive effect on energy conservation.

Are some areas of the building heated unnecessarily? (Basements and storage areas are common culprits). Let the building owner know about this, but also point out that heating ducts and water pipes in unheated areas should be insulated so that heat is not lost.

Don't drop efforts on behalf of energy conservation after one letter or conversation with the owner. Be persistent. Energy waste will continue until enough people care to do something about it.

A TWO-WAY STREET

Rising energy costs affect building owner and tenant alike. If heat is included in rental fees, the building owner is realizing lower profits and tenants can expect a rent increase at lease renewal time. If apartments are separately metered but the building is not weather tight, tenants will be unhappy with high fuel costs and will look for more economical and energy-efficient apartments. By making building improvements that conserve energy and by installing separate electric and/or gas meters, a building owner can give the tenant an incentive to conserve energy and will maintain a competitive position in the apartment marketplace.

TIPS FOR THE OCCUPANT

There are many ways to conserve energy in the apartment. Small, consistent efforts by each individual adds up to big savings for everyone.

The thermostat should be kept set between 65° and 68°F during the day and set back to 60°F at night. Don't "fiddle" with a thermostat setting; it wastes energy. If chilly, put on a sweater and warm socks. Keep heat registers, radiators, or baseboard heating units free of dust and don't block them with furniture.

Air conditioners, while often of great benefit to apartment dwellers, consume high amounts of energy. An energy advocate uses a cooling unit prudently. If a cool apartment is desired when coming home from work, a timer can be connected to the unit and set to go on a half-hour before arrival time. A thermostat setting of 78°F or above is recommended for air conditioned areas. Place a window unit in the window of the apartment that is most protected from direct sunlight. Keep windows and doors closed when a air conditioner is running and close draperies and/or shades on sunny windows, but don't block air going to and from the cooling unit.

The hot water, which is usually taken for granted in the apartment, requires large amounts of energy to heat it. Instead of baths, take quick showers-it uses less hot water. Try to cut down on the number of times the dishwasher is used. Run only full loads, preferable in the early morning or late evening when energy demands on utility companies are lowest. If washing dishes by hand, don't let water run continuously; fill a pan with hot water for rinsing. Use as low a water temperature for washing clothes as will give satisfactory cleaning; use cold water for rinsing.

Because single-pane glass is a poor insulator, a great deal of heat can be lost through windows. Plasticized roller shades, tightly sealed on all edges, can considerably reduce this type of heat loss. When choosing more elaborate window coverings, select glass fiber draperies lined with insulated materials. A cornice over the top of the draperies will prevent a draft tunnel effect. On overcast winter days and at night, keep shades and draperies closed; open them on sunny days to take advantage of solar heat. In summer, keep windows closed and covered during the hottest hours of the day; open windows, top and bottom, after sunset. If possible, open windows opposite one another to get cross ventilation.

Energy is often unwittingly wasted. As your sense of energy awareness heightens, you will no doubt find many ways to conserve energy in addition to those outlined here. The following list will give an idea of some of these.

HEATING AND COOLING

- Keep doors and windows tightly closed. Losing heat or air conditioning through open doors and windows is wasteful and costly.
- Furnace and air conditioning filters should be cleaned or replaced monthly during their season of use. Your apartment manager may provide filter service. It's a good idea, however, to find out where filters are located within your apartment and to vacuum them regularly, winter and summer.
- If you have a fireplace, be sure the damper stays closed when you don't have a fire going. Otherwise, you're wasting a lot of energy up the chimney.
- Kitchen and bathroom exhaust fans should be run sparingly, as they can remove 100-300 cubic feet of heated or air conditioned air each minute.
- Registers within each room for supplying and returning air should not be obstructed with furniture or draperies. Keep the air flowing freely for more efficient and economical operation.
- Thermal-lined draperies give added insulation against the hot sun and cold wind.

COOLING

Keeping your apartment comfortably cool can account for 50 percent or more of all your electric use during the air conditioning season.

That's why it is important to eliminate all wasteful use and to develop energy-wise habits.

- There's no need to overcool and waste energy and money. For each degree below 78, you'll use five percent more energy.
- Before going to bed and before leaving for the day, turn the thermostat up five degrees during the cooling season. If you're leaving for several days, turn the air conditioner off.
- Close draperies during the day to help keep heat out of your air conditioned apartment.
- Use heat-producing appliances (oven, dishwasher, dryer) during early morning or late evening hours to cut down on the amount of heat generated inside your apartment. The cooler your apartment stays, the less air conditioning required. Turning off unnecessary lights helps, too.

HEATING

In winter, heating accounts for the largest portion of your electric use if your apartment is heated electrically. You can hold down operating costs by giving careful attention to factors that affect electrical use.

- Keep in mind temperature variances throughout the day, and avoid overheating. For each degree above 68 you'll use five percent more energy which will be reflected in higher electrical costs.
- Before going to bed and before leaving for the day, turn the thermostat down five degrees. If you're leaving for several days, turn the thermostat down, but never off during the heating season. A sudden drop in outside temperature could cause water pipes to freeze while you're away.
- Report any drafts around windows and doors to your apartment manager.
- If you sleep with an open window, close your bedroom door so the cold air does not reach your thermostat and cause the rest of the apartment to overheat.
- Draperies can serve as an insulator to help keep heat inside your apartment and prevent costly air infiltration. Keep draperies closed except on sunny days.

APPLIANCES

Refrigerators / Freezers

- Manual defrost refrigerators should be defrosted as soon as frost becomes 1/4" thick. Any more ice than that reduces the motor's cooling power and uses more electricity.

- When defrosting, clean the grill or vent at the bottom of the refrigerator as well as the evaporator pan inside.

- Occasionally, remove dust from the condenser coils (radiator-like rods on back or bottom of unit).

- Excessive door opening wastes electricity and money. Before opening refrigerator or freezer, know what you're looking for and remove several food and beverages at one time, when possible.

- To be sure doors close tightly, check the rubber gasket around the inside of your refrigerator and freezer doors. If loose, advise your manager.

- Avoid loose, overcrowding refrigerator shelves so cold air circulates freely.

- Your refrigerator and freezer temperature controls should be set to run only as cold as is necessary.

- Your freezer, unlike the refrigerator, operates most efficiently when full.

Dishwasher

- Wait until you have a full load before running the dishwasher. This saves many gallons of hot water as well as detergent and energy to heat the water and run the dishwasher.

- Use only detergent made specifically for dishwashers. Other cleaning agents can block the washing action, causing overflow and possible damage to the appliance.

- If your dishwasher has a filter screen, clean it often.

- Since the dishwasher gives off heat and humidity, operate it during hot weather in the cooler morning or evening hours.

- If you have questions about your dishwasher, consult the operating manual or your apartment manager.

Range

- Use flat bottom utensils that fit the size of the surface units so that heat goes directly into the pan. Tight fitting lids keep the heat inside and shorten cooking time.
- Use the lowest possible setting for surface units. Food will look better, taste better and cost less to cook.
- Preheat oven only for foods requiring precise temperatures. Meats, casseroles, and most foods requiring more than an hour to cook do not require a preheated oven.
- Save time and electricity by cooking complete meals in the oven and by baking extra food to freeze for future use.
- Use a minimum amount of water for surface cooking, and don't lift covers and stir more than necessary.
- Reduce cooking time by completely thawing foods before cooking.
- For boiling water, use a kettle instead of an open pan.
- Keep oven door closed when in use. Frequent opening allows heat to escape and energy to be wasted.
- Never use oven to heat your apartment.

Water Heater

- Reach for the cold water first if it will do the job. Use only as much hot water as needed.
- Avoid letting hot water run constantly while washing dishes, shaving, or similar uses.
- Take quick showers instead of tub baths.
- Report all leaking and dripping faucets to your apartment manager. A leaking hot water faucet can waste considerably energy and water over a month's time.
- A lower temperature setting for hot water will reduce energy use and costs. Ask your manager about this.

Laundry

- If your washer does not have a water level control, plan to use full loads when possible. But beware of overloading, which reduces the machine's efficiency drastically.

- Clean the lint filter thoroughly before every load--washing or drying.
- Much of the energy used in doing your laundry goes to heat the water for washing. When warm or cold water will do the job instead of hot water, use it.
- Use the proper setting for the size load you intend to wash.
- Most dryers have several temperature choices. Select the lower temperature or "no heat" setting as often as possible.
- Sort clothes by thickness so you won't have to run an additional cycle for only one or two slow-drying items.

Lighting

- Turn off lights not being used. This is especially important in summer because light produces heat.
- Dust can reduce your lighting efficiency by one-half, so keep bulbs and fixtures clean.

Others

- The rule of "turn it off when not in use" applies to most energy consuming devices. This includes the radio, television, electric blankets, room heaters, irons, and hair dryers.
- If you need an extension cord, use a heavy-duty one and then for short distances only. Frayed cords are safety hazards.
- Keep all appliances clean and in good working order. Electricity is too good to waste.

For additional information on energy conservation in the apartment, check other sections of this manual. The sections on Heat Loss (Unit 2), Weatherization Options (Unit 3), Heating Systems (Unit 4), and Energy and Appliance Use (Unit 5) should be especially useful.

unit 8

ENERGY IN THE MOBILE HOME

by: V.W. Deluca

With declining energy resources and increasing cost facing us, the need to conserve energy is pressing. This need applies equally to occupants of houses, apartments, and mobile homes. Whether a mobile home owner or whether considering the purchase of a new home there are several steps that can be taken to save energy and money and, at the same time, make the home more comfortable.

Home Energy Conservation Primer

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unit 8

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Purchasing A Mobile Home

The best insurance in owning an energy efficient mobile home is to take into consideration influential factors when purchasing a home.

Most mobile homes produced since 1970 have been built to national standards established by the American National Standards Institute (ANSI 119.1) and the National Fire Protection Association (NFPA 501B). These standards cover the construction of the body and frame, plumbing, and the heating and electrical systems of the mobile home. If the homes are not designed to meet the needs and location of the owner, excessive heat loss and energy consumption will result. Mobile homes built according to the ANSI and NFPA Standards, display a sticker (usually attached to the electric box door) indicating the zone that this home is built for. The sticker includes a map and description of each zone and the performance expected from the heating system within a specified range of temperature and wind velocity.

Also, when buying a mobile home, buy according to Mobile Home Construction and Safety Standards established by the U.S. Department of Housing and Urban Development (HUD), effective June 15, 1976. A mobile home built according to Subpart F of the Standards meets the basic HUD requirements for thermal insulation (in the ceiling, walls, and floor), air infiltration, and condensation control, and has a permanently affixed label of certification on an interior wall. The certification label will give the climate conditions for which the mobile home is suited and the capacity of the heating and cooling equipment. The climate of the northern part of the United States requires Zone II certification. The standards are the result of research by mobile home manufacturers and insulation engineers. A home insulated to HUD's performance standards is more comfortable in winter and summer and is more economical to operate than a home with less thermal protection.

Some mobile homes manufactured today exceed minimum HUD performance standards for thermal protection and are labeled with "Energy Conservation Home" tags, as well as HUD heating and cooling certificates. From these the owner can expect even greater comfort and economy of operation.

Recently HUD has announced that the Federal Mobile Homes Construction and Safety Standards are being considered for revisions and up-dating. The areas being considered for revision are:

- fire safety
- egress safety
- transportation

- ENERGY CONSERVATION
- structural system performance
- wind safety
- protection against freezing
- glazing requirements

The items under energy conservation that are being considered for revision are:

- Should the thermal transmission coefficient for climate zones be revised?
- Should the total window and door area be reduced?
- What additional requirements should be imposed to prevent condensation in the wall, ceiling and floor cavities of the mobile home?
- Should the use of storm windows or insulated glass be required for all climatic zones?
- What requirements can be established to more effectively control heat losses from air infiltration?
- Should minimum levels of air infiltration be established to insure that the air quality does not go below limits which could impair the occupant?
- Should controls be established to limit the amount of air pollutants, such as formaldehyde, in the living space of a mobile home?
- What criteria should be established for determining acceptability of insulating materials?

(Reprinted from: Federal Register 6-7-79, Vol. 44, No. 111)

SITE SELECTION

There are four factors that will be discussed with respect to selecting a site or modifying an existing site for energy conservation.

- SUN - source of heat and light
- WIND - the direction and velocity affects potential heat loss or gain and ventilation

- TOPOGRAPHY - land forms can effect the site micro climate: wind, temperature and solar radiation

- VEGETATION - effect the site micro-climate: solar radiation wind, humidity and air temperature

Sun

The sun is a source of energy that can be desirable or undesirable depending on the season. In the winter a mobile home can act as a low-grade solar collector to aid in space heating. In the summer, direct solar radiation can cause excessive heat build up.

If possible, a mobile home should be placed on a east-west orientation so that they long side of the walls do not receive intense east and west sunlight. (The long wall should face north and south). Vegetation can also shade the home from intense summer radiation. Large deciduous trees can shade the mobile home in the summer to reduce excessive heat gain. In the winter, deciduous trees loose their leaves allowing the home helping to heat it. Properly designed and positioned awnings, patio louvers, and overhangs can also aid in shading a mobile home in the summer. Figure 8.2.

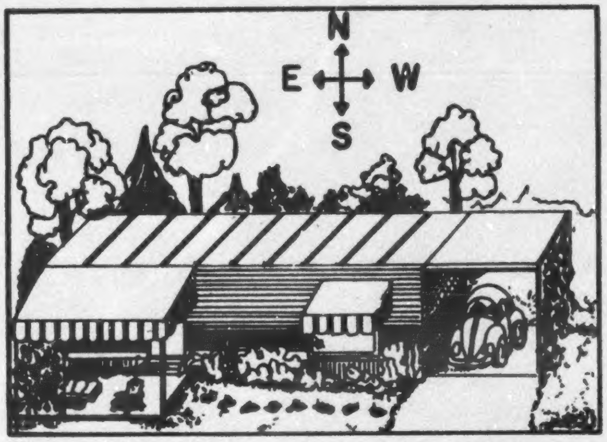


Figure 8.1 (N.Y. State Cooperative Extension)

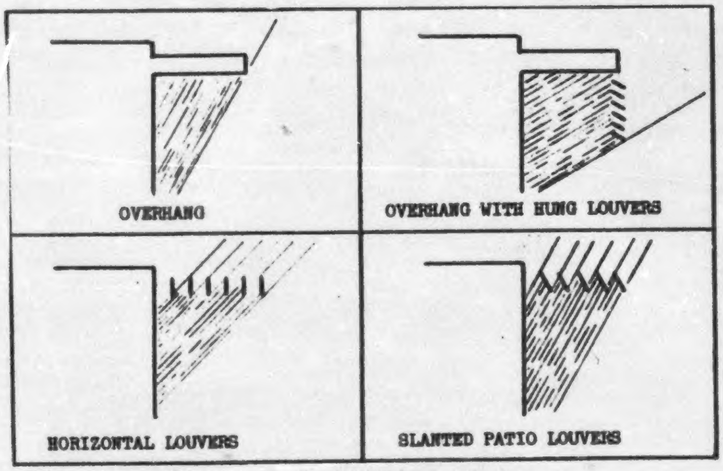


Figure 8.2 Shading Devices

Grass and shrubs planted along the base of a mobile home will absorb and deflect the glare of the sunlight reducing the radiant heat in the interior of the home. Plant materials can reduce summer temperatures of the immediate area by 10 to 14%.

Light colored drapes can also deflect summer sunlight resulting in lower interior temperatures. Similarly by allowing the sunlight to enter unobstructed windows in the winter can aid in heating the home. This is especially effective on the southern exposed windows since the position of the sun is south during the winter months in the northern hemisphere. It is important to note that the heat gain through windows during the day can be lost through the windows at night so it is advantageous to close heavy drapes at sunset to reduce heat transfer. Insulated shutters can also be made from 1" polystyrene plastic board. Temperatures can be controlled by placing the shutter in the window opening when the sun goes down to retain day time heat, and taking it out when the sun comes up to admit sunshine and heat. (See Unit 3 Section III for more information on insulated shutters.)

Wind

Wind can either be beneficial or destructive for energy savings. It is important to know the direction of summer and winter prevailing winds to manipulate this factor. The wind direction can be found by contacting the local airport or meterology station and/or by monitoring the wind direction for several days during each season. In general, winter winds prevail from the north and west. The actual direction depends on the climate and topography of the immediate area.

Protection from the winter winds can be achieved by planting a windbreak of evergreens along the north and west orientation. Fences, carports and other buildings may also serve as windbreak The windbreak should be planted at a distance from the home 5 to 20 times the height of the mobile home for maximum protection. This can reduce the velocity of the wind by 30% before it reaches the home. Low growing shrubs planted in this orientation can also decrease the wind velocity another 10%.

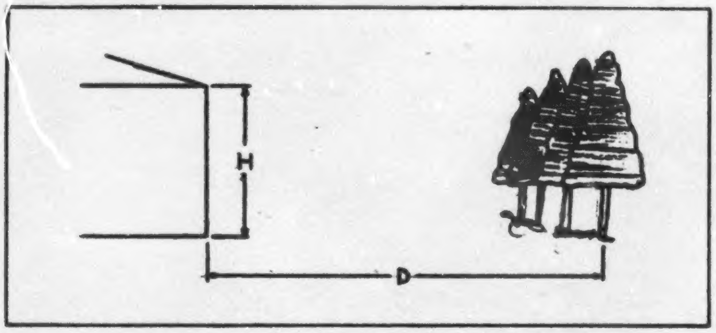
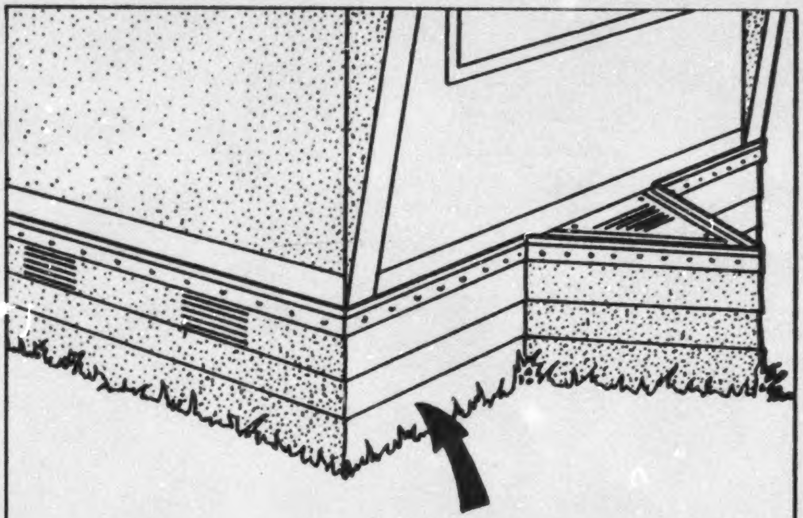


Figure 8.3 The Distance (D) of a Windbreak Should be 5 to 20 Times the Height (H) of the Home

Skirting

Another type of windbreak and a very effective energy conservation measure for the mobile home is the addition of a skirt which encloses the area around the base of the mobile home.



Properly installed skirting reduces heat loss.

Figure 8.4 (N.Y. State Cooperative Extension)

Any rigid board or panel construction corrugated steel or aluminum sheets that match the home are commonly used. Other options are plywood, chip board, and fiberglass. Complete skirting kits are available at most local building suppliers and mobile home sales.

When installing skirting, vents should be provided at the front and rear of the skirting to allow air to circulate. Venting prevents moisture build-up, and provides air for the heating system. Before installing skirting check to be sure that the undercovering and insulation are secured to the unit and free from tears and holes. If the home is forced air heated, all the duct work is in the floor section and should be insulated and undercovered. Also, check pipes which are exposed to the elements. Water pipes should be wrapped with heat cable and insulated to prevent freezing. Heat cable is available with an automatic thermostat that is set to turn on at 35° and off at 45°F.

INSULATION

Heat loss in the mobile home is due to transmission and infiltration. Transmission heat-loss is due to the building materials conduction of the heat through the walls, windows, floors and roof. Insulation is used to reduce transmission losses. The best way to insure proper insulation is to evaluate the insulation quality of the home at the time of purchase. Manufacturers should indicate the R-value of the insulation in the walls, roof and floor. (The R-value is the standard to measure a materials' resistance to heat transmission. The higher the R-value the better the insulation.) It is especially important to consider the R-value of exterior walls at the time of purchase.

Table 1 Selection Chart For Heating Band--8 watts/ft.

Method of wrapping pipe	Length needed per foot of pipe	Protection provided without outer wrap		Protection provided with outer wrap	
		3/8"	1/2"	3/8"	1/2"
Straight along pipe	1'	-25°F	-20°F	-50°F	-45°F
3 turns/ft.	1'-1"	-30°F	-25°F	-55°F	-50°F
6 turns/ft.	1'-4"	-50°F	-45°F	-60°F	-55°F

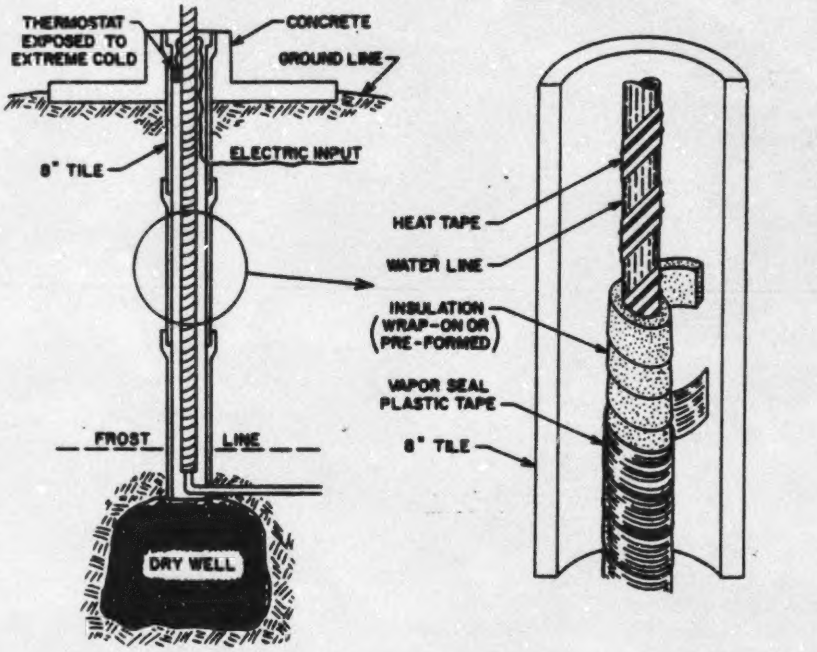

THERMOSTAT EXPOSED TO EXTREME COLD
CONCRETE
GROUND LINE
8" TILE
ELECTRIC INPUT
FROST LINE
DRY WELL
HEAT TAPE
WATER LINE
INSULATION (WRAP-ON OR PRE-FORMED)
VAPOR SEAL PLASTIC TAPE
8" TILE

Figure 8.5
FREEZE-PROOFING A WATER PIPE

Due to the techniques used in mobile home construction, it is very difficult to add insulation to this area without extensive remodeling. Fiberglass insulation can be added under the home by using chicken wire, heavy gauge wire or "tiger-tooth" wire bands to hold it in place. Rigid foam insulation can also be attached to the underside of the home. It can also be added to the interior sub-floor or ceiling if remodeling is going to follow. Rigid foam insulation is very flammable and should be covered with 1/2 inch of non-flammable materials such as gypsum board. (Check the insulation manufacturers specification.)

To insulate the roof of a mobile home, a ureathane foam materials is quite effective in reducing heat loss in the winter and heat build up in the summer. This process involves spraying foam on the roof to a thickness of 2-3 inches. Ureathane is also a flammable material and should be sealed.

Mobile homes can also be insulated using cellulose fiber insulation. If proper precautions are taken, cellulose can be very effective. Fuel savings of 50% to 65% have been reported. A few tips for using cellulose are listed below:

- Many mobile homes have a plastic vapor barrier on ceilings and walls. With filled wall cavities, inside ventilation in the kitchen, bathroom, utility room, or wherever there is moist heat needed.
- The sealing of plugs is also very important. If they leak, moisture will get into the cellulose causing it to force the metal to bulge. If this were to happen, it would be necessary to remove the material that is/was wet. (Cellulose that has been wet will lose its fire retardancy.)

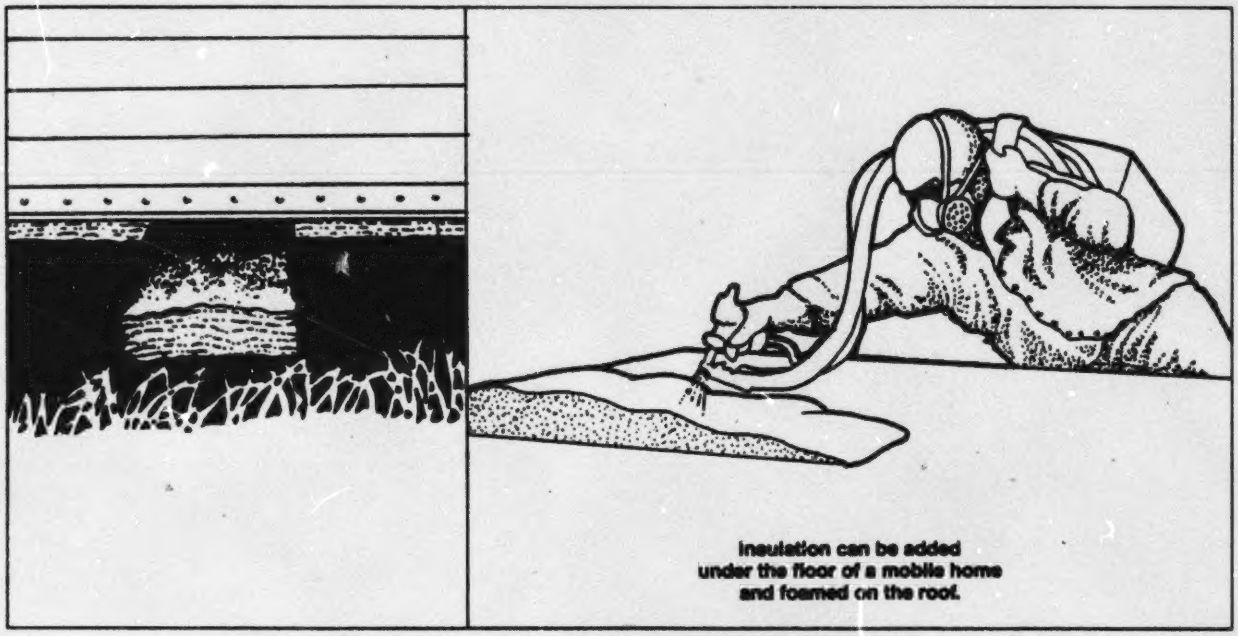
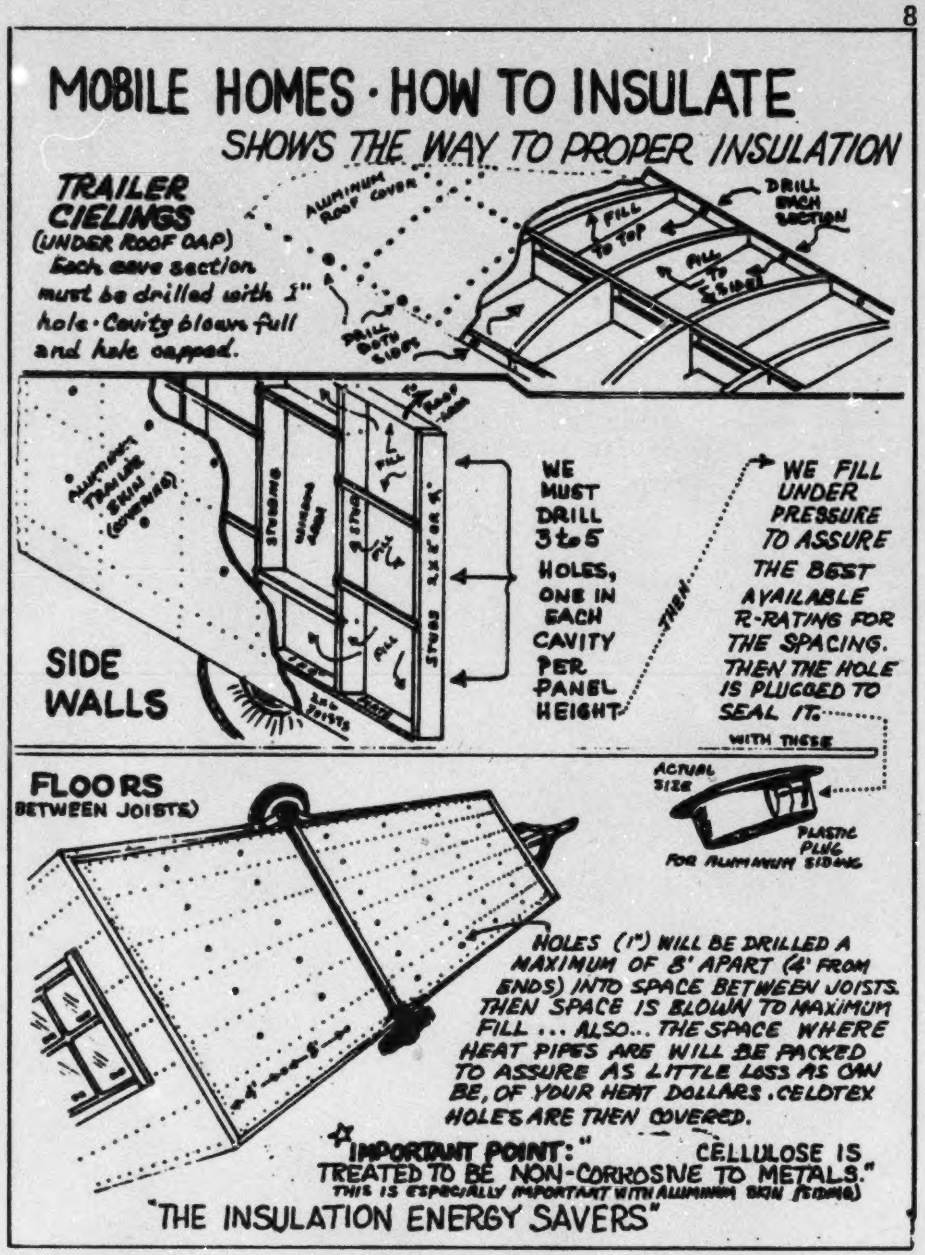

Insulation can be added under the floor of a mobile home and foamed on the roof.

Figure 8.6 (N.Y. State Cooperative Extension)

INFILTRATION

Heat loss by infiltration is the heat loss by air entering through cracks and crevices which exist in every home. Infiltration causes anywhere from 1/4 to 1/3 of the total heat loss in a mobile home. It is unaffected by insulation because insulation is porous and only prevents transmission losses.

Stopping air infiltration falls to weatherstripping and caulking. Both caulking and weatherstripping are economical do-it-yourself projects. Unit III provides all the information necessary for properly inspecting, purchasing and installing caulking and weatherstripping.


8
ALUMINUM ROOF COVER
DRILL EACH SECTION
FILL TO TOP
FILL TO SIDES
DRILL BOTH SIDES
ALUMINUM TRAILER SKIN (COVERING)
STUDDING
STUDS
2 X 2" OR 4"
FILL
2x6 JOISTS
WITH THESE
ACTUAL SIZE
PLASTIC PLUG FOR ALUMINUM SIDING
THEN

MOBILE HOMES · HOW TO INSULATE

SHOWS THE WAY TO PROPER INSULATION

TRAILER CIELINGS (UNDER ROOF CAP)

Each eave section must be drilled with 1" hole · Cavity blown full and hole capped.

SIDE WALLS

WE MUST DRILL 3 to 5 HOLES, ONE IN EACH CAVITY PER PANEL HEIGHT

WE FILL UNDER PRESSURE TO ASSURE THE BEST AVAILABLE R-RATING FOR THE SPACING. THEN THE HOLE IS PLUGGED TO SEAL IT.

FLOORS (BETWEEN JOISTS)

HOLES (1") WILL BE DRILLED A MAXIMUM OF 8' APART (4' FROM ENDS) INTO SPACE BETWEEN JOISTS. THEN SPACE IS BLOWN TO MAXIMUM FILL ... ALSO ... THE SPACE WHERE HEAT PIPES ARE WILL BE PACKED TO ASSURE AS LITTLE LOSS AS CAN BE, OF YOUR HEAT DOLLARS. CELOTEX HOLES ARE THEN COVERED.

☆ IMPORTANT POINT: " CELLULOSE IS TREATED TO BE NON-CORROSIVE TO METALS." THIS IS ESPECIALLY IMPORTANT WITH ALUMINUM SKIN (SIDING)

"THE INSULATION ENERGY SAVERS"

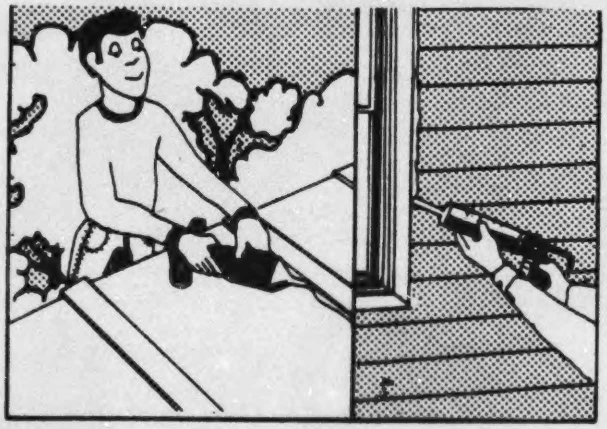


Figure 8.7 Caulking the Roof and Windows Reduces Air Leakage (N.Y. State Cooperative Extension)

STORM WINDOWS

The 1976 HUD standards require storm windows or insulating glass in mobile homes. If storm windows are not available for your present mobile home, or even if storm windows are in place, the installation of a 4 to 6 mil plastic sheeting over windows will reduce heat loss. It is advisable to leave one or two windows on the south side of the home uncovered in case there is a warm day when an open window would be desirable. Plastic sheeting can be held in place on the outside of a home with duct tape or other pressure-sensitive tape which can be removed at the end of the heating season. Lightweight rigid plastic can also be purchased in kit form. The panels are easily installed and removed each season.

HEATING

Mobile homes use electric, gas or oil heating systems which are fully automatic. Gas and oil systems heat air which is distributed through ducts to each room. The duct work is usually run under the floor so it is important that it is insulated to prevent heat loss. A visual inspection will locate areas that should be repaired.

Gas and oil systems are automatically controlled by a thermostat that is centrally located. A good duct system has registers that can be adjusted to control air flow. Heat can be concentrated where it is needed such as living areas, bathroom and study areas. Through experimentation, it is possible to regulate the temperature of each room to meet specific comfort needs.

An electric heat system will likely be one of two types. One type uses individual electric baseboard. Heating units which permit separate temperature regulation for each room. The second type is a centrally located electric resistance system which is similar to gas and oil systems.so similar measures can be used to maximize its performance.

Heating systems of the mobile home must comply with federal standards. For this reason, there is a good chance that the furnace is oversized for the home. This is because the zone is defined for extreme climate conditions. When the capacity of the furnace extends the demand, energy is wasted. To check this compare the zone and standards set for the heating system by ANSI with the actual climate. If you suspect that your furnace is oversize, a qualified serviceman can make the proper adjustment which will save approximately 20% of the energy consumed. (See Unit 4 "Heating Systems" for more information or furnace modification.)

Consider these factors to insure a well maintained efficient furnace:

- dust radiators or baseboard
- insure that the fresh air intake is not blocked or obstructed
- clean furnace filters and the interior of the furnace cabinet and blower assembly regularly
- read owners manual and follow maintenance schedule
- have the system checked annually by a qualified serviceman

AIR CONDITIONING

Mobile homes can be equipped with central or room unit air conditioning.

Most mobile homes use an air conditioning system that is an integral part of the furnace cabinet. Air conditioning pipes should be well insulated and free from kinks for maximum efficiency. This system uses the same ducts as the heating system so similar maintenance and control should be used to maximize the efficiency of your cooling system. The air conditioning system is automatic and uses the same thermostats as the heating system with a switch to set the temperature.

If a window-room air conditioning unit is used, it is important to choose one that suits the size of the mobile home. A proper size air conditioner cools and dehumidifies providing more comfort with greater efficiency.

Determining the size of an air conditioner is rather an extensive job. Influential factors such as insulation qualities, window area, floor area, type of construction, surrounding area, vegetation and color of the home must be considered for precise calculation. A rule of thumb is to figure 12,000 Btus for each 500 square feet of floor area. This method, however, is far from being an accurate measurement for cooling requirements.

VENTILATION

Many people fail to realize the cooling effect of the night summer breeze. The proper utilization of window venting can result in a very comfortable environment without the use of energy consuming air conditioning.

After determining the prevailing wind direction, the windows can be opened to allow a flow of air to circulate through the home. Before sunrise, close the window and drapes to retain the interior temperatures as long as possible. Keep the storm window on the windows that do not influence the ventilation. This will reduce the amount of warm air that will have to be cooled by the air conditioner during the day.

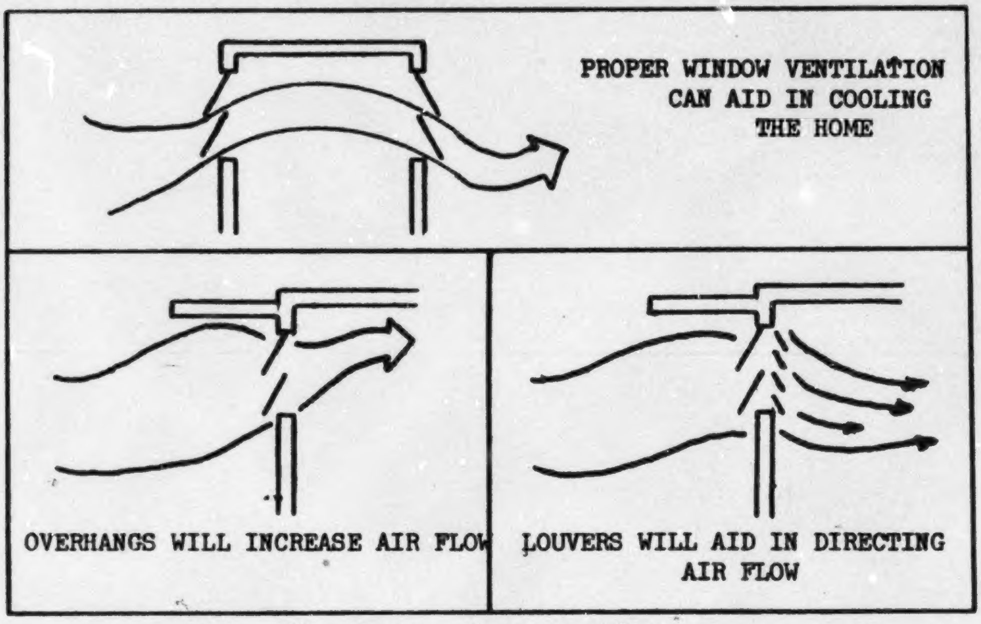

PROPER WINDOW VENTILATION CAN AID IN COOLING THE HOME
OVERHANGS WILL INCREASE AIR FLOW
LOUVERS WILL AID IN DIRECTING AIR FLOW

Figure 8.8 Window Ventilation

For additional information on energy conservation in the mobile home, check other units in the PRIMER. The sections on Heat Loss (Unit 2), Weatherization (Unit 3), Heating Systems (Unit 4), and Energy and Home Appliances (Unit 5) should be especially useful.

PRIMER STUDY GUIDES

UNIT 1 - ENERGY IN PERSPECTIVE

1. What is meant by a "nonrenewable" energy source? Give examples.
2. What are estimated years supply of reserves based on and what must be remembered when considering reserve estimates?
3. What are some of the major reasons for the "energy crisis" in the United States?
4. Give at least three reasons for conserving energy.
5. Briefly explain the 3 types of conservation strategies and their expected effects.
6. What can the rapid growth in residential energy consumption over the last 25 years be attributed to?
7. What consuming sector currently uses the most energy in the U.S.? the least?
8. What fuel is the U.S. most dependent on for energy?
9. What factors have to be considered when predicting future energy use patterns?
10. What is meant by a "renewable" energy source? Give some examples.

UNIT 2 - HEAT TRANSFER

1. Define the following:
   Heat:
   BTU:
   Heat loss:
   Heat gain:
2. List and define three forms of heat transfer.
3. Name five locations in the house where heat loss takes place.
4. Define the following:
   "U" factor:
   "K" factor:
   "C" factor:
   "R" factor:
5. Define the following:
   Inside Design Temperature:
   Outside Design Temperature:
   Design Temperature Difference:
   Degree Day:

   How do they relate to each other?

UNIT 3 - WEATHERIZATION

1. Define and relate weatherization to energy conservation.
2. Recognize the advantage of weatherizing for reducing heat transfer.
3. Identify various home weatherization measures as to reduction of air infiltration and heat transfer.
4. Identify areas of the home in which caulking and weatherstripping might be applied to reduce heat loss.
5. Identify window and door treatments which would reduce heat transfer.
6. Identify areas of the home in which insulation may be placed.
7. Identify types, kinds, and applications for all weatherizing options.
8. Identify relationship of weatherization and humidity in the home.

UNIT 4 - HEATING SYSTEMS

1. List five types of electric heating units.
2. What three fossil fuels are used for heat?
3. Name the three major types of furnaces.
4. What conditions indicate an oversize furnace?
   Undersized?
5. List three advantages and disadvantages for each type of heating system.
6. List several do-it-yourself furnace maintenance ideas.
7. Give three ways wood can be used as an economical fuel.
8. Why are fireplaces poor heaters?
9. Give three ways to improve fireplace efficiency?
10. Why are air-tight wood stoves better heaters than fireplaces?
11. Why should firewood be seasoned?
12. Do all softwoods have low heat values? Are all hardwoods high in heat value?
13. Why should chimneys be cleaned periodically?

UNIT 5 - ENERGY AND APPLIANCES

1. On the average, how much total household energy used is used for hot water heating?
2. What is the highest recommended temperature setting for a water heater?
3. Why should the clothes dryer be vented outside?
4. What water temperature is recommended for a dishwasher?
5. How much of the total gas consumed by a range is used by the pilot lights?
6. What are the recommended temperatures for the refrigerator and freezer?
7. What is the highest wattage and amperage rating acceptable for an electric heater used in the home?
8. What is EER and why is it used?
9. Why should storm windows be left in place if air condition is used?
10. What is a BTU?
11. What is a therm?
12. An electric meter records electricity use in what unit?
13. A gas meter records has use in what units?

UNIT 6 - ENERGY EFFICIENT DESIGN (EED)

1. On what side of a house should deciduous trees be planted? Why?
2. On which side of a house should the majority of windows be placed?
3. What is the most energy efficient shape for a house?
4. What is the minimum roof overhang recommended for south-facing windows?
5. Where should windows be placed for maximum effectiveness?
6. What is recommended value for walls? Ceilings? Floors?
7. Where should vapor barriers be installed?
8. Why should heat ducts be insulated?

9. Why is it important to have properly sized heating equipment?
10. Which is better, a light-colored roof or one of a darker shade? Why?
11. Name three recommended locations for fluorescent lighting in a home.
12. Why is fluorescent lighting preferable to incandescent lighting in most cases?

UNIT 7 - ENERGY AND THE APARTMENT

1. Name several things to look for in selecting and renting an apartment? (in reference to energy conservation)
2. What is the energy advantage of having an apartment complex adjacent to another apartment?
3. What is an "Apartment Energy Advocate?"
4. How can an apartment occupant act as an effective "Energy Advocate?"
5. What are some window treatments an apartment occupant can incorporate to make the apartment more comfortable?
6. What are some energy conservation tips for apartment occupants in the following categories?

    (1) Heating
    (2) Cooling
    (3) Appliances
        a. Refrigerator
        b. Range
        c. Water Heater
        d. Laundry
        e. Dishwasher
        f. Lighting

UNIT 8 - ENERGY AND THE MOBILE HOME

1. In what direction should a mobile home be placed for maximum energy efficiency?
2. Name four methods of reducing the chilling effect of prevailing winds.
3. What are some methods of shading a mobile home?
4. What techniques can be used to upgrade insulation on a mobile home? What are the dangers of adding urethane or other panel-type insulations?
5. What is skirting and what does it do? How is it applied?

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